TIGHT BINDING BOOK

REPORT

OF THE

EIGHTY-THIRD MEETING OF THE

BRITISH ASSOCIATION

FOR THE ADVANCEMENT OF SCIENCE

BIRMINGHAM: 1913

SEPTEMBER 10-17

LONDON
JOHN MURRAY, ALBEMARLE STREET
1914

Office of the Association: Burlington House, London, W.

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LIST OF PLATES.

OFFICERS AND COUNCIL, 1913-1914.

PATRON.

HIS MAJESTY THE KING.

PRESIDENT.

SIR OLIVER J. LODGE, D.Sc., LL.D., F.R.S.

VICE-PRESIDENTS.

The Right Hon. the Lord Mayor of Birmingham (Lieut.-Col. E. MARTINEAU, M.A., V.D.).
The Right Hon. the EARL OF CRAVEN, Lord-Lieutenant of Warwickshire.
The Worshipful the High Sheriff of Warwickshire (Sir F. E. WALLER, Bart.).
The Right Hon. the EARL OF COVENTRY, Lord-Lieutenant of Worcestershire.
The Right Hon. the EARL OF DARTMOUTH, V.D., Lord-Lieutenant of Staffordshire.
The Right Rev. the Lord Bishop of Birmingham (Dr. H. RUSSELL WAKEFIELD).
The Right Hon. JOSEPH CHAMBERLAIN, D.C.L., M.P., Chancellor of the University of Birmingham.
The Vice-Chancellor of the University of Birmingham (GILBERT BARLING, M.B., F.R.C.S.).
The Right Hon. JESSE COLLINGS, M.P., Hon. President of the Birmingham Chamber of Commerce.
Alderman the Right Hon. WILLIAM KENRICK.
The Deputy Lord Mayor of Birmingham (Alderman W. H. BOWATER).
Professor CHARLES LAPWORTH, LL.D., F.R.S.
Professor J. H. POYNTING, Sc.D., F.R.S.

PRESIDENT ELECT.

Professor WILLIAM BATESON, M.A., F.R.S.

VICE-PRESIDENTS ELECT.

His Excellency the Governor-General of the Commonwealth of Australia.
Their Excellencies the Governors of New South Wales, Victoria, Queensland, South Australia, Western Australia, Tasmania.
The Honourable the Prime Minister of the Commonwealth.
The Honourable the Premiers of New South Wales, Victoria, Queensland, South Australia, Western Australia, Tasmania.
The Right Honourable the Lord Mayors of Sydney and Melbourne.
The Right Worshipful the Mayors of Brisbane, Adelaide, Perth, Hobart.
The Chancellors of the Universities of Sydney, Melbourne, Adelaide, Tasmania, Queensland, Western Australia.

GENERAL TREASURER.

Professor JOHN PERRY, D.Sc., LL.D., F.R.S.

GENERAL SECRETARIES.

Professor W. A. HERDMAN, D.Sc., F.R.S. | Professor H. H. TURNER, D.Sc., D.C.L., F.R.S.

ASSISTANT SECRETARY.

O. J. R. HOWARTH, M.A., Burlington House, London, W.

CHIEF CLERK AND ASSISTANT TREASURER.

H. C. STEWARDSON, Burlington House, London, W.

FEDERAL COUNCIL FOR THE AUSTRALIAN MEETING.

President: THE HON. THE PRIME MINISTER OF THE COMMONWEALTH.
Chairman: Professor ORME MASSON, M.A., D.Sc., F.R.S.
Secretary: M. L. SHEPHERD, Prime Minister's Department, Melbourne.

GENERAL ORGANISING SECRETARY FOR THE AUSTRALIAN MEETING.

A. C. D. RIVETT, B.A., D.Sc., University of Melbourne, Victoria.

[P.T.O.

LOCAL OFFICERS FOR THE AUSTRALIAN MEETING.

NEW SOUTH WALES.—*Chairman:* Professor T. W. EDGEWORTH DAVID, C.M.G., D.Sc., F.R.S.
Secretary: J. H. MAIDEN, F.L.S.
Treasurer: H. G. CHAPMAN, M.D., B.S.

VICTORIA.—*Chairman:* Professor ORME MASSON, M.A., D.Sc., F.R.S.
Secretary: Professor BALDWIN SPENCER, M.A., C.M.G., F.R.S.
Treasurer: FREDERICK WHITE.

QUEENSLAND.—*Chairman:* Professor B. D. STEELE, D.Sc.
Secretary: T. E. JONES, B.A.

SOUTH AUSTRALIA.—*Chairman:* Professor E. C. STIRLING, M.D., D.Sc., F.R.S.
Secretary: Professor KERR GRANT, M.Sc.
Treasurer: THOMAS GILL.

WESTERN AUSTRALIA.—*Chairman:* Sir WINTHROP HACKETT, K.C.M.G., LL.D.
Secretary: JAMES S. BATTYE, M.A., LL.B.

ORDINARY MEMBERS OF THE COUNCIL.

ARMSTRONG, Professor H. E., F.R.S.
BRABROOK, Sir EDWARD, C.B.
BRAGG, Professor W. H., F.R.S.
CLERK, Dr. DUGALD, F.R.S.
CRAIGIE, Major P. G., C.B.
CROOKE, W., B.A.
DENDY, Professor A., F.R.S.
DIXEY, Dr. F. A., F.R.S.
DIXON, Professor H. B., F.R.S.
FARMER, Professor J. B., F.R.S.
GRIFFITHS, Principal E. H., F.R.S.
HADDON, Dr. A. C., F.R.S.
HALL, A. D., F.R.S.
HALLIBURTON, Professor W. D., F.R.S.
IM THURN, Sir E. F., K.C.M.G.
LODGE, ALFRED, M.A.
LYONS, Captain H. G., F.R.S.
MARR, Dr. J. E., F.R.S.
MELDOLA, Professor R., F.R.S.
MYRES, Professor J. L., M.A.
PRAIN, Sir DAVID, C.I.E., F.R.S.
SHERRINGTON, Professor C. S., F.R.S.
TEALL, Dr. J. J. H., F.R.S.
THOMPSON, Dr. SILVANUS P., F.R.S.
TROUTON, Professor F. T., F.R.S.

EX-OFFICIO MEMBERS OF THE COUNCIL.

The Trustees, past Presidents of the Association, the President and Vice-Presidents for the year, the President and Vice-Presidents Elect, past and present General Treasurers and General Secretaries, past Assistant General Secretaries, and the Local Treasurers and Local Secretaries for the ensuing Annual Meeting.

TRUSTEES (PERMANENT).

The Right Hon. Lord RAYLEIGH, O.M., M.A., D.C.L., LL.D., F.R.S., F.R.A.S.
Sir ARTHUR W. RÜCKER, M.A., D.Sc., LL.D., F.R.S.
Major P. A. MACMAHON, D.Sc., LL.D., F.R.S., F.R.A.S.

PAST PRESIDENTS OF THE ASSOCIATION.

Lord Rayleigh, D.C.L., F.R.S.
Sir H. E. Roscoe, D.C.L., F.R.S.
Sir A. Geikie, O.M., K.C.B., F.R.S.
Sir W. Crookes, O.M., Pres.R.S.
Sir W. Turner, K.C.B., F.R.S.
Sir A. W. Rücker, D.Sc., F.R.S.
Sir James Dewar, LL.D., F.R.S.
Sir Norman Lockyer, K.C.B., F.R.S.
Arthur J. Balfour, D.C.L., F.R.S.
Sir E. Ray Lankester, K.C.B., F.R.S.
Sir Francis Darwin, F.R.S.
Sir J. J. Thomson, O.M., F.R.S.
Prof. T. G. Bonney, Sc.D., F.R.S.
Sir W. Ramsay, K.C.B., F.R.S.
Sir E. A. Schafer, LL.D., F.R.S.

PAST GENERAL OFFICERS OF THE ASSOCIATION.

Prof. T. G. Bonney, Sc.D., F.R.S.
A. Vernon Harcourt, D.C.L., F.R.S.
Sir A. W. Rücker, D.Sc., F.R.S.
Sir E. A. Schäfer, LL.D., F.R.S.
Dr. D. H. Scott, M.A., F.R.S.
Dr. G. Carey Foster, F.R.S.
Dr. J. G. Garson.
Major P. A. MacMahon, F.R.S.

AUDITORS.

Sir Edward Brabrook, C.B. | Professor H. McLeod, LL.D., F.R.S.

RULES OF THE BRITISH ASSOCIATION.

[*Adopted by the General Committee at Leicester,* 1907, *with subsequent amendments.*]

CHAPTER I.

Objects and Constitution.

1. The objects of the British Association for the Advancement of Science are: To give a stronger impulse and a more systematic direction to scientific inquiry; to promote the intercourse of those who cultivate Science in different parts of the British Empire with one another and with foreign philosophers; to obtain more general attention for the objects of Science and the removal of any disadvantages of a public kind which impede its progress. Objects.

The Association contemplates no invasion of the ground occupied by other Institutions.

2. The Association shall consist of Members, Associates, and Honorary Corresponding Members. Constitution.

The governing body of the Association shall be a General Committee, constituted as hereinafter set forth; and its affairs shall be directed by a Council and conducted by General Officers appointed by that Committee.

3. The Association shall meet annually, for one week or longer, and at such other times as the General Committee may appoint. The place of each Annual Meeting shall be determined by the General Committee not less than two years in advance; and the arrangements for these meetings shall be entrusted to the Officers of the Association. Annual Meetings.

CHAPTER II.

The General Committee.

1. The General Committee shall be constituted of the following persons:— Constitution.

(i) *Permanent Members*—

(*a*) Past and present Members of the Council, and past and present Presidents of the Sections.

(*b*) Members who, by the publication of works or papers, have furthered the advancement of knowledge in any of those departments which are assigned to the Sections of the Association.

(ii) *Temporary Members*—

(*a*) Vice-Presidents and Secretaries of the Sections.
(*b*) Honorary Corresponding Members, foreign representatives, and other persons specially invited or nominated by the Council or General Officers.
(*c*) Delegates nominated by the Affiliated Societies.
(*d*) Delegates—not exceeding altogether three in number—from Scientific Institutions established at the place of meeting.

Admission. 2. The decision of the Council on the qualifications and claims of any Member of the Association to be placed on the General Committee shall be final.

(i) Claims for admission as a Permanent Member must be lodged with the Assistant Secretary at least one month before the Annual Meeting.
(ii) Claims for admission as a Temporary Member may be sent to the Assistant Secretary at any time before or during the Annual Meeting.

Meetings. 3. The General Committee shall meet twice at least during every Annual Meeting. In the interval between two Annual Meetings, it shall be competent for the Council at any time to summon a meeting of the General Committee.

Functions. 4. The General Committee shall

(i) Receive and consider the report of the Council.
(ii) Elect a Committee of Recommendations.
(iii) Receive and consider the report of the Committee of Recommendations.
(iv) Determine the place of the Annual Meeting not less than two years in advance.
(v) Determine the date of the next Annual Meeting.
(vi) Elect the President and Vice-Presidents, Local Treasurer, and Local Secretaries for the next Annual Meeting.
(vii) Elect Ordinary Members of Council.
(viii) Appoint General Officers.
(ix) Appoint Auditors.
(x) Elect the officers of the Conference of Delegates.
(xi) Receive any notice of motion for the next Annual Meeting.

Chapter III.

Committee of Recommendations.

Constitution.

1. * The *ex officio* Members of the Committee of Recommendations are the President and Vice-Presidents of the Association, the President of each Section at the Annual Meeting, the Chairman of the Conference of Delegates, the General Secretaries, the General Treasurer, the Trustees, and the Presidents of the Association in former years.

An Ordinary Member of the Committee for each Section shall be nominated by the Committee of that Section.

If the President of a Section be unable to attend a meeting of the Committee of Recommendations, the Sectional Committee may appoint a Vice-President, or some other member of the Committee, to attend in his place, due notice of such appointment being sent to the Assistant Secretary.

Functions.

2. Every recommendation made under Chapter IV. and every resolution on a scientific subject, which may be submitted to the Association by any Sectional Committee, or by the Conference of Delegates, or otherwise than by the Council of the Association, shall be submitted to the Committee of Recommendations. If the Committee of Recommendations approve such recommendation, they shall transmit it to the General Committee; and no recommendation shall be considered by the General Committee that is not so transmitted.

Every recommendation adopted by the General Committee shall, if it involve action on the part of the Association, be transmitted to the Council; and the Council shall take such action as may be needful to give effect to it, and shall report to the General Committee not later than the next Annual Meeting.

Every proposal for establishing a new Section or Sub-Section, for altering the title of a Section, or for any other change in the constitutional forms or fundamental rules of the Association, shall be referred to the Committee of Recommendations for their consideration and report.

Procedure.

3. The Committee of Recommendations shall assemble, for the despatch of business, on the Monday of the Annual Meeting, and, if necessary, on the following day. Their Report must be submitted to the General Committee on the last day of the Annual Meeting.

* Amended by the General Committee at Winnipeg, 1909.

Chapter IV.

Research Committees.

Procedure. 1. Every proposal for special research, or for a grant of money in aid of special research, which is made in any Section, shall be considered by the Committee of that Section; and, if such proposal be approved, it shall be referred to the Committee of Recommendations.

In consequence of any such proposal, a Sectional Committee may recommend the appointment of a Research Committee, composed of Members of the Association, to conduct research or administer a grant in aid of research, and in any case to report thereon to the Association; and the Committee of Recommendations may include such recommendation in their report to the General Committee.

Constitution. 2. Every appointment of a Research Committee shall be proposed at a meeting of the Sectional Committee and adopted at a subsequent meeting. The Sectional Committee shall settle the terms of reference and suitable Members to serve on it, which must be as small as is consistent with its efficient working; and shall nominate a Chairman and a Secretary. Such Research Committee, if appointed, shall have power to add to their numbers.

Proposals by Sectional Committees. 3. The Sectional Committee shall state in their recommendation whether a grant of money be desired for the purposes of any Research Committee, and shall estimate the amount required.

All proposals sanctioned by a Sectional Committee shall be forwarded by the Recorder to the Assistant Secretary not later than noon on the Monday of the Annual Meeting for presentation to the Committee of Recommendations.

Tenure 4. Research Committees are appointed for one year only. If the work of a Research Committee cannot be completed in that year, application may be made through a Sectional Committee at the next Annual Meeting for reappointment, with or without a grant—or a further grant—of money.

Reports. 5. Every Research Committee shall present a Report, whether interim or final, at the Annual Meeting next after that at which it was appointed or reappointed. Interim Reports, whether intended for publication or not, must be submitted in writing. Each Sectional Committee shall ascertain whether a Report has been made by each Research Committee appointed on their recommendation, and shall report to the Committee of Recommendations on or before the Monday of the Annual Meeting.

6. In each Research Committee to which a grant of money has been made, the Chairman is the only person entitled to call on the General Treasurer for such portion of the sum granted as from time to time may be required.

GRANTS. (*a*) Drawn by Chairman.

Grants of money sanctioned at the Annual Meeting expire on June 30 following. The General Treasurer is not authorised, after that date, to allow any claims on account of such grants.

(*b*) Expire on June 30.

The Chairman of a Research Committee must, before the Annual Meeting next following the appointment of the Research Committee, forward to the General Treasurer a statement of the sums that have been received and expended, together with vouchers. The Chairman must then return the balance of the grant, if any, which remains unexpended; provided that a Research Committee may, in the first year of its appointment only, apply for leave to retain an unexpended balance when or before its report is presented, due reason being given for such application.*

(*c*) Accounts and balance in hand.

When application is made for a Committee to be reappointed, and to retain the balance of a former grant, and also to receive a further grant, the amount of such further grant is to be estimated as being sufficient, together with the balance proposed to be retained, to make up the amount desired.

(*d*) Additional Grant.

In making grants of money to Research Committees, the Association does not contemplate the payment of personal expenses to the Members.

(*e*) *Caveat.*

A Research Committee, whether or not in receipt of a grant, shall not raise money, in the name or under the auspices of the Association, without special permission from the General Committee.

7. Members and Committees entrusted with sums of money for collecting specimens of any description shall include in their Reports particulars thereof, and shall reserve the specimens thus obtained for disposal, as the Council may direct.

Disposal of specimens, apparatus, &c.

Committees are required to furnish a list of any apparatus which may have been purchased out of a grant made by the Association, and to state whether the apparatus is likely to be useful for continuing the research in question or for other specific purposes.

All instruments, drawings, papers, and other property of the Association, when not in actual use by a Committee, shall be deposited at the Office of the Association.

* Amended by the General Committee at Dundee, 1912.

CHAPTER V.

The Council.

Constitution. 1. The Council shall consist of *ex officio* Members and of Ordinary Members elected annually by the General Committee.

(i) The *ex officio* Members are—the Trustees, past Presidents of the Association, the President and Vice-Presidents for the year, the President and Vice-Presidents Elect, past and present General Treasurers and General Secretaries, past Assistant General Secretaries, and the Local Treasurers and Local Secretaries for the ensuing Annual Meeting.

(ii) The Ordinary Members shall not exceed twenty-five in number. Of these, not more than twenty shall have served on the Council as Ordinary Members in the previous year.

Functions. 2. The Council shall have authority to act, in the name and on behalf of the Association, in all matters which do not conflict with the functions of the General Committee.

In the interval between two Annual Meetings, the Council shall manage the affairs of the Association and may fill up vacancies among the General and other Officers, until the next Annual Meeting.

The Council shall hold such meetings as they may think fit, and shall in any case meet on the first day of the Annual Meeting, in order to complete and adopt the Annual Report, and to consider other matters to be brought before the General Committee.

The Council shall nominate for election by the General Committee, at each Annual Meeting, a President and General Officers of the Association.

Suggestions for the Presidency shall be considered by the Council at the Meeting in February, and the names selected shall be issued with the summonses to the Council Meeting in March, when the nomination shall be made from the names on the list.

The Council shall have power to appoint and dismiss such paid officers as may be necessary to carry on the work of the Association, on such terms as they may from time to time determine.

3. Election to the Council shall take place at the same time as that of the Officers of the Association. Elections.

(i) At each Annual Election, the following Ordinary Members of the Council shall be ineligible for re-election in the ensuing year:

(*a*) Three of the Members who have served for the longest consecutive period, and

(*b*) Two of the Members who, being resident in or near London, have attended the least number of meetings during the past year.

Nevertheless, it shall be competent for the Council, by an unanimous vote, to reverse the proportion in the order of retirement above set forth.

(ii) The Council shall submit to the General Committee, in their Annual Report, the names of twenty-three Members of the Association whom they recommend for election as Members of Council.

(iii) Two Members shall be elected by the General Committee, without nomination by the Council; and this election shall be at the same meeting as that at which the election of the other Members of the Council takes place.

Any member of the General Committee may propose another member thereof for election as one of these two members of Council, and, if only two are so proposed, they shall be declared elected; but, if more than two are so proposed, the election shall be by show of hands, unless five members at least require it to be by ballot.

Chapter VI.

The President, General Officers, and Staff.

1. The President assumes office on the first day of the Annual Meeting, when he delivers a Presidential Address. He resigns office at the next Annual Meeting, when he inducts his successor into the Chair. The President.

The President shall preside at all meetings of the Association or of its Council and Committees which he attends in his capacity as President. In his absence, he shall be represented by a Vice-President or past President of the Association.

2. The General Officers of the Association are the General Treasurer and the General Secretaries. General Officers.

It shall be competent for the General Officers to act, in the name of the Association, in any matter of urgency which cannot be brought under the consideration of the Council; and they shall report such action to the Council at the next meeting.

The General Treasurer.

3. The General Treasurer shall be responsible to the General Committee and the Council for the financial affairs of the Association.

The General Secretaries.

4. The General Secretaries shall control the general organisation and administration, and shall be responsible to the General Committee and the Council for conducting the correspondence and for the general routine of the work of the Association, excepting that which relates to Finance.

The Assistant Secretary.

5. The Assistant Secretary shall hold office during the pleasure of the Council. He shall act under the direction of the General Secretaries, and in their absence shall represent them. He shall also act on the directions which may be given him by the General Treasurer in that part of his duties which relates to the finances of the Association.

The Assistant Secretary shall be charged, subject as aforesaid: (i) with the general organising and editorial work, and with the administrative business of the Association; (ii) with the control and direction of the Office and of all persons therein employed; and (iii) with the execution of Standing Orders or of the directions given him by the General Officers and Council. He shall act as Secretary, and take Minutes, at the meetings of the Council, and at all meetings of Committees of the Council, of the Committee of Recommendations, and of the General Committee.

Assistant Treasurer.

6. The General Treasurer may depute one of the Staff, as Assistant Treasurer, to carry on, under his direction, the routine work of the duties of his office.

The Assistant Treasurer shall be charged with the issue of Membership Tickets, the payment of Grants, and such other work as may be delegated to him.

Chapter VII.

Finance.

Financial Statements.

1. The General Treasurer, or Assistant Treasurer, shall receive and acknowledge all sums of money paid to the Association. He shall submit, at each meeting of the Council, an *interim* statement of his Account; and, after

June 30 in each year, he shall prepare and submit to the General Committee a balance-sheet of the Funds of the Association.

2. The Accounts of the Association shall be audited, annually, by Auditors appointed by the General Committee. **Audit.**

3. The General Treasurer shall make all ordinary payments authorised by the General Committee or by the Council. **Expenditure.**

4. The General Treasurer is empowered to draw on the account of the Association, and to invest on its behalf, part or all of the balance standing at any time to the credit of the Association in the books of the Bank of England, either in Exchequer Bills or in any other temporary investment, and to change, sell, or otherwise deal with such temporary investment as may seem to him desirable. **Investments.**

5. In the event of the General Treasurer being unable, from illness or any other cause, to exercise the functions of his office, the President of the Association for the time being and one of the General Secretaries shall be jointly empowered to sign cheques on behalf of the Association. **Cheques.**

CHAPTER VIII.

The Annual Meetings.

1. Local Committees shall be formed to assist the General Officers in making arrangements for the Annual Meeting, and shall have power to add to their number. **Local Officers and Committees.**

2. The General Committee shall appoint, on the recommendation of the Local Reception or Executive Committee for the ensuing Annual Meeting, a Local Treasurer or Treasurers and two or more Local Secretaries, who shall rank as officers of the Association, and shall consult with the General Officers and the Assistant Secretary as to the local arrangements necessary for the conduct of the meeting. The Local Treasurers shall be empowered to enrol Members and Associates, and to receive subscriptions.

3. The Local Committees and Sub-Committees shall undertake the local organisation, and shall have power to act in the name of the Association in all matters pertaining to the local arrangements for the Annual Meeting other than the work of the Sections. **Functions.**

Chapter IX.

The Work of the Sections.

The Sections.

1. The scientific work of the Association shall be transacted under such Sections as shall be constituted from time to time by the General Committee.

It shall be competent for any Section, if authorised by the Council for the time being, to form a Sub-Section for the purpose of dealing separately with any group of communications addressed to that Section.

Sectional Officers.

2. There shall be in each Section a President, two or more Vice-Presidents, and two or more Secretaries. They shall be appointed by the Council, for each Annual Meeting in advance, and shall act as the Officers of the Section from the date of their appointment until the appointment of their successors in office for the ensuing Annual Meeting.

Of the Secretaries, one shall act as Recorder of the Section, and one shall be resident in the locality where the Annual Meeting is held.

Rooms.

3. The Section Rooms and the approaches thereto shall not be used for any notices, exhibitions, or other purposes than those of the Association.

Sectional Committees.

4. The work of each Section shall be conducted by a Sectional Committee, which shall consist of the following :—

Constitution.

(i) The Officers of the Section during their term of office.
(ii) All past Presidents of that Section.
(iii) Such other Members of the Association, present at any Annual Meeting, as the Sectional Committee, thus constituted, may co-opt for the period of the meeting :

Provided always that—

Privilege of Old Members.

(*a*) Any Member of the Association who has served on the Committee of any Section in any previous year, and who has intimated his intention of being present at the Annual Meeting, is eligible as a member of that Committee at their first meeting.

Daily Co-optation

(*b*) A Sectional Committee may co-opt members, as above set forth, at any time during the Annual Meeting, and shall publish daily a revised list of the members.

(c) A Sectional Committee may, at any time during the Annual Meeting, appoint not more than three persons present at the meeting to be Vice-Presidents of the Section, in addition to those previously appointed by the Council. Additional Vice-Presidents.

5. The chief executive officers of a Section shall be the President and the Recorder. They shall have power to act on behalf of the Section in any matter of urgency which cannot be brought before the consideration of the Sectional Committee; and they shall report such action to the Sectional Committee at its next meeting. EXECUTIVE FUNCTIONS

The President (or, in his absence, one of the Vice-Presidents) shall preside at all meetings of the Sectional Committee or of the Section. His ruling shall be absolute on all points of order that may arise. Of President

The Recorder shall be responsible for the punctual transmission to the Assistant Secretary of the daily programme of his Section, of the recommendations adopted by the Sectional Committee, of the printed returns, abstracts, reports, or papers appertaining to the proceedings of his Section at the Annual Meeting, and for the correspondence and minutes of the Sectional Committee. and of Recorder.

6. The Sectional Committee shall nominate, before the close of the Annual Meeting, not more than six of its own members to be members of an Organising Committee, with the officers to be subsequently appointed by the Council, and past Presidents of the Section, from the close of the Annual Meeting until the conclusion of its meeting on the first day of the ensuing Annual Meeting. Organising Committee.

Each Organising Committee shall hold such Meetings as are deemed necessary by its President for the organisation of the ensuing Sectional proceedings, and shall hold a meeting on the first Wednesday of the Annual Meeting: to nominate members of the Sectional Committee, to confirm the Provisional Programme of the Section, and to report to the Sectional Committee.

Each Sectional Committee shall meet daily, unless otherwise determined, during the Annual Meeting: to co-opt members, to complete the arrangements for the next day, and to take into consideration any suggestion for the advancement of Science that may be offered by a member, or may arise out of the proceedings of the Section. Sectional Committee.

No paper shall be read in any Section until it has been accepted by the Sectional Committee and entered as accepted on its Minutes. Papers and Reports.

Any report or paper read in any one Section may be read also in any other Section.

No paper or abstract of a paper shall be printed in the Annual Report of the Association unless the manuscript has been received by the Recorder of the Section before the close of the Annual Meeting.

Recommendations.

It shall be within the competence of the Sectional Committee to review the recommendations adopted at preceding Annual Meetings, as published in the Annual Reports of the Association, and the communications made to the Section at its current meetings, for the purpose of selecting definite objects of research, in the promotion of which individual or concerted action may be usefully employed; and, further, to take into consideration those branches or aspects of knowledge on the state and progress of which reports are required: to make recommendations and nominate individuals or Research Committees to whom the preparation of such reports, or the task of research, may be entrusted, discriminating as to whether, and in what respects, these objects may be usefully advanced by the appropriation of money from the funds of the Association, whether by reference to local authorities, public institutions, or Departments of His Majesty's Government. The appointment of such Research Committees shall be made in accordance with the provisions of Chapter IV.

No proposal arising out of the proceedings of any Section shall be referred to the Committee of Recommendations unless it shall have received the sanction of the Sectional Committee.

Publication.

7. Papers ordered to be printed *in extenso* shall not be included in the Annual Report, if published elsewhere prior to the issue of the Annual Report in volume form. Reports of Research Committees shall not be published elsewhere than in the Annual Report without the express sanction of the Council.

Copyright.

8. The copyright of papers ordered by the General Committee to be printed *in extenso* in the Annual Report shall be vested in the authors; and the copyright of the reports of Research Committees appointed by the General Committee shall be vested in the Association.

Chapter X.

Admission of Members and Associates.

1. No technical qualification shall be required on the part of an applicant for admission as a Member or as an Associate of the British Association; but the Council is empowered, in the event of special circumstances arising, to impose suitable conditions and restrictions in this respect. Applications.

* Every person admitted as a Member or an Associate shall conform to the Rules and Regulations of the Association, any infringement of which on his part may render him liable to exclusion by the Council, who have also authority, if they think it necessary, to withhold from any person the privilege of attending any Annual Meeting or to cancel a ticket of admission already issued. Obligations.

It shall be competent for the General Officers to act, in the name of the Council, on any occasion of urgency which cannot be brought under the consideration of the Council; and they shall report such action to the Council at the next Meeting.

2. All Members are eligible to any office in the Association. Conditions and Privileges of Membership.

(i) Every *Life Member* shall pay, on admission, the sum of Ten Pounds.

Life Members shall receive *gratis* the Annual Reports of the Association.

(ii) Every *Annual Member* shall pay, on admission, the sum of Two Pounds, and in any subsequent year the sum of One Pound.

Annual Members shall receive *gratis* the Report of the Association for the year of their admission and for the years in which they continue to pay, *without intermission*, their annual subscription. An Annual Member who omits to subscribe for any particular year shall lose for that and all future years the privilege of receiving the Annual Reports of the Association *gratis*. He, however, may resume his other privileges as a Member at any subsequent Annual Meeting by paying on each such occasion the sum of One Pound.

(iii) Every *Associate* for a year shall pay, on admission, the sum of One Pound.

* Amended by the General Committee at Dublin, 1908.

Associates shall not receive the Annual Report gratuitously. They shall not be eligible to serve on any Committee, nor be qualified to hold any office in the Association.

(iv) *Ladies* may become Members or Associates on the same terms as gentlemen, or can obtain a *Lady's Ticket* (transferable to ladies only) on the payment of One Pound.

Corresponding Members.

3. Corresponding Members may be appointed by the General Committee, on the nomination of the Council. They shall be entitled to all the privileges of Membership.

Annual Subscriptions.

4. Subscriptions are payable at or before the Annual Meeting. Annual Members not attending the meeting may make payment at any time before the close of the financial year on June 30 of the following year.

The Annual Report.

5. The Annual Report of the Association shall be forwarded *gratis* to individuals and institutions entitled to receive it.

Annual Members whose subscriptions have been intermitted shall be entitled to purchase the Annual Report at two-thirds of the publication price; and Associates for a year shall be entitled to purchase, at the same price, the volume for that year.

Volumes not claimed within two years of the date of publication can only be issued by direction of the Council.

Chapter XI.

Corresponding Societies: Conference of Delegates.

Corresponding Societies are constituted as follows:

AFFILIATED SOCIETIES.

1. (i) Any Society which undertakes local scientific investigation and publishes the results may become a Society *affiliated* to the British Association.

Each Affiliated Society may appoint a Delegate, who must be or become a Member of the Association and must attend the meetings of the Conference of Delegates. He shall be *ex officio* a Member of the General Committee.

ASSOCIATED SOCIETIES.

(ii) Any Society formed for the purpose of encouraging the study of Science, which has existed for three years and numbers not fewer than fifty members, may become a Society *associated* with the British Association.

Each Associated Society shall have the right to appoint a Delegate to attend the Annual Conference. Such Delegates must be or become either Members or Associates of the British Association, and shall have all the rights of Delegates appointed by the Affiliated Societies, except that of membership of the General Committee.

2. Application may be made by any Society to be placed on the list of Corresponding Societies. Such application must be addressed to the Assistant Secretary on or before the 1st of June preceding the Annual Meeting at which it is intended it should be considered, and must, in the case of Societies desiring to be affiliated, be accompanied by specimens of the publications of the results of local scientific investigations recently undertaken by the Society. Applications.

3. A Corresponding Societies Committee shall be annually nominated by the Council and appointed by the General Committee, for the purpose of keeping themselves generally informed of the work of the Corresponding Societies and of superintending the preparation of a list of the papers published by the Affiliated Societies. This Committee shall make an Annual Report to the Council, and shall suggest such additions or changes in the list of Corresponding Societies as they may consider desirable. CORRESPONDING SOCIETIES COMMITTEE.

(i) Each Corresponding Society shall forward every year to the Assistant Secretary of the Association, on or before June 1, such particulars in regard to the Society as may be required for the information of the Corresponding Societies Committee. Procedure

(ii) There shall be inserted in the Annual Report of the Association a list of the papers published by the Corresponding Societies during the preceding twelve months which contain the results of local scientific work conducted by them—those papers only being included which refer to subjects coming under the cognisance of one or other of the several Sections of the Association.

4. The Delegates of Corresponding Societies shall constitute a Conference, of which the Chairman, Vice-Chairman, and Secretary or Secretaries shall be nominated annually by the Council and appointed by the General Committee. The members of the Corresponding Societies Committee shall be *ex officio* members of the Conference. CONFERENCE OF DELEGATES.

(i) The Conference of Delegates shall be summoned by the Secretaries to hold one or more meetings during Procedure and Functions.

each Annual Meeting of the Association, and shall be empowered to invite any Member or Associate to take part in the discussions.

(ii) The Conference of Delegates shall be empowered to submit Resolutions to the Committee of Recommendations for their consideration, and for report to the General Committee.

(iii) The Sectional Committees of the Association shall be requested to transmit to the Secretaries of the Conference of Delegates copies of any recommendations to be made to the General Committee bearing on matters in which the co-operation of Corresponding Societies is desirable. It shall be competent for the Secretaries of the Conference of Delegates to invite the authors of such recommendations to attend the meetings of the Conference in order to give verbal explanations of their objects and of the precise way in which they desire these to be carried into effect.

(iv) It shall be the duty of the Delegates to make themselves familiar with the purport of the several recommendations brought before the Conference, in order that they may be able to bring such recommendations adequately before their respective Societies.

(v) The Conference may also discuss propositions regarding the promotion of more systematic observation and plans of operation, and of greater uniformity in the method of publishing results.

Chapter XII.

Amendments and New Rules.

Alterations. Any alterations in the Rules, and any amendments or new Rules that may be proposed by the Council or individual Members, shall be notified to the General Committee on the first day of the Annual Meeting, and referred forthwith to the Committee of Recommendations; and, on the report of that Committee, shall be submitted for approval at the last meeting of the General Committee.

TRUSTEES, GENERAL OFFICERS, &c., 1831-1913

TRUSTEES.

1832-70 (Sir) R. I. MURCHISON (Bart.), F.R.S.
1832-62 JOHN TAYLOR, Esq., F.R.S.
1832-39 C. BABBAGE, Esq., F.R.S.
1839-44 F. BAILY, Esq., F.R.S.
1844-58 Rev. G. PEACOCK, F.R.S.
1858-82 General E. SABINE, F.R.S.
1862-81 Sir P. EGERTON, Bart., F.R.S.
1872-1913 Sir J. LUBBOCK, Bart. (afterwards Lord AVEBURY), F.R.S.
1881-83 W. SPOTTISWOODE, Esq., Pres. R.S.
1883- Lord RAYLEIGH, F.R.S.
1883-98 Sir LYON (afterwards Lord) PLAYFAIR, F.R.S.
1898- Prof. (Sir) A. W. RÜCKER, F.R.S.
1913- Major P. A. MACMAHON, F.R.S.

GENERAL TREASURERS.

1831 JONATHAN GRAY, Esq.
1832-62 JOHN TAYLOR, Esq., F.R.S.
1862-74 W. SPOTTISWOODE, Esq., F.R.S.
1874-91 Prof. A. W. WILLIAMSON, F.R.S.
1891-98 Prof. (Sir) A. W. RÜCKER, F.R.S.
1898-1904 Prof. G. C. FOSTER, F.R.S.
1904- Prof. JOHN PERRY, F.R.S.

GENERAL SECRETARIES.

1832-35 Rev. W. VERNON HARCOURT, F.R.S.
1835-36 Rev. W. VERNON HARCOURT, F.R.S., and F. BAILY, Esq., F.R.S.
1836-37 Rev. W. VERNON HARCOURT, F.R.S., and R. I. MURCHISON, Esq., F.R.S.
1837-39 R. I. MURCHISON, Esq., F.R.S., and Rev. G. PEACOCK, F.R.S.
1839-45 Sir R. I. MURCHISON, F.R.S., and Major E. SABINE, F.R.S.
1845-50 Lieut.-Colonel E. SABINE, F.R.S.
1850-52 General E. SABINE, F.R.S., and J. F. ROYLE, Esq., F.R.S.
1852-53 J. F. ROYLE, Esq., F.R.S.
1853-59 General E. SABINE, F.R.S.
1859-61 Prof. R. WALKER, F.R.S.
1861-62 W. HOPKINS, Esq., F.R.S.
1862-63 W. HOPKINS, Esq., F.R.S., and Prof. J. PHILLIPS, F.R.S.
1863-65 W. HOPKINS, Esq., F.R.S., and F. GALTON, Esq., F.R.S.
1865-66 F. GALTON, Esq., F.R.S.
1866-68 F. GALTON, Esq., F.R.S., and Dr. T. A. HIRST, F.R.S.
1868-71 Dr. T. A. HIRST, F.R.S., and Dr. T. THOMSON, F.R.S.
1871-72 Dr. T. THOMSON, F.R.S., and Capt. DOUGLAS GALTON, F.R.S.
1872-76 Capt. D. GALTON, F.R.S., and Dr. MICHAEL FOSTER, F.R.S.
1876-81 Capt. D. GALTON, F.R.S., and Dr. P. L. SCLATER, F.R.S.
1881-82 Capt. D. GALTON, F.R.S., and Prof. F. M. BALFOUR, F.R.S.
1882-83 Capt. DOUGLAS GALTON, F.R.S.
1883-95 Sir DOUGLAS GALTON, F.R.S., and A. G. VERNON HARCOURT, Esq., F.R.S.
1895-97 A. G. VERNON HARCOURT, Esq., F.R.S., and Prof. E. A. SCHÄFER, F.R.S.
1897-1900 Prof. SCHÄFER, F.R.S., and Sir W. C. ROBERTS-AUSTEN, F.R.S.
1900-02 Sir W. C. ROBERTS-AUSTEN, F.R.S., and Dr. D. H. SCOTT, F.R.S.
1902-03 Dr. D. H. SCOTT, F.R.S., and Major P. A. MACMAHON, F.R.S.
1903-13 Major P. A. MACMAHON, F.R.S., and Prof. W. A. HERDMAN, F.R.S.
1913- Prof. W. A. HERDMAN, F.R.S., and Prof. H. H. TURNER, F.R.S.

ASSISTANT GENERAL SECRETARIES, &c.: 1831-1904.

1831 JOHN PHILLIPS, Esq., *Secretary.*
1832 Prof. J. D. FORBES, *Acting Secretary.*
1832-62 Prof. JOHN PHILLIPS, F.R.S.
1862-78 G. GRIFFITH, Esq., M.A.
1881 G. GRIFFITH, Esq., M.A., *Acting Secretary.*
1881-85 Prof. T. G. BONNEY, F.R.S., *Secretary.*
1885-90 A. T. ATCHISON, Esq., M.A., *Secretary.*
1890 G. GRIFFITH, Esq., M.A., *Acting Secretary.*
1890-1902 G. GRIFFITH, Esq., M.A.
1902-04 J. G. GARSON, Esq., M.D.

ASSISTANT SECRETARIES.

1878-80 J. E. H. GORDON, Esq., B.A.
1904-09 A. SILVA WHITE, Esq.
1909- O. J. R. HOWARTH, Esq., M.A.

Presidents and Secretaries of the Sections of the Association, 1901–1913.

SECTION A.[1]—MATHEMATICS AND PHYSICS.

Date and Place	Presidents	Secretaries
1901. Glasgow ...	Major P. A. MacMahon, F.R.S.—*Dep. of Astronomy*, Prof. H. H. Turner, F.R.S.	H. S. Carslaw, C. H. Lees, W. Stewart, Prof. L. R. Wilberforce.
1902. Belfast......	Prof. J. Purser, LL.D., M.R.I.A.—*Dep. of Astronomy*, Prof. A. Schuster, F.R.S.	H. S. Carslaw, A. R. Hinks, A. Larmor, C. H. Lees, Prof. W. B. Morton, A. W. Porter.
1903. Southport	C. Vernon Boys, F.R.S.—*Dep. of Astronomy and Meteorology*, Dr. W. N. Shaw, F.R.S.	D. E. Benson, A. R. Hinks, R. W. H. T. Hudson, Dr. C. H. Lees, J. Loton, A. W. Porter.
1904. Cambridge	Prof. H. Lamb, F.R.S.—*Sub-Section of Astronomy and Cosmical Physics*, Sir J. Eliot, K.C.I.E., F.R.S.	A. R. Hinks, R. W. H. T. Hudson, Dr. C. H. Lees, Dr. W. J. S. Lockyer, A. W. Porter, W. C. D. Whetham.
1905. SouthAfrica	Prof. A. R. Forsyth, M.A., F.R.S.	A. R. Hinks, S. S. Hough, R. T. A. Innes, J. H. Jeans, Dr C. H. Lees.
1906. York.........	Principal E. H. Griffiths, F.R.S.	Dr. L. N. G. Filon, Dr. J. A. Harker, A. R. Hinks, Prof. A. W. Porter, H. Dennis Taylor.
1907. Leicester ...	Prof. A. E. H. Love, M.A., F.R.S.	E. E. Brooks, Dr. L. N. G. Filon, Dr. J. A. Harker, A. R. Hinks, Prof. A. W. Porter.
1908. Dublin	Dr. W. N. Shaw, F.R.S.	Dr. W. G. Duffield, Dr. L. N. G. Filon, E. Gold, Prof. J. A. McClelland, Prof. A. W. Porter, Prof. E. T. Whittaker.
1909. Winnipeg	Prof. E. Rutherford, F.R.S ...	Prof. F. Allen, Prof. J. C. Fields, E. Gold, F. Horton, Prof. A. W. Porter, Dr. A. A. Rambaut.
1910. Sheffield ...	Prof. E. W. Hobson, F.R.S....	H. Bateman, A. S. Eddington, E. Gold, Dr. F. Horton, Dr. S. R. Milner, Prof. A. W. Porter.
1911. Portsmouth	Prof. H. H. Turner, F.R.S. ...	H. Bateman, Prof. P. V. Bevan, A. S. Eddington, E. Gold, Prof. A. W. Porter, P. A. Yapp.
1912. Dundee ...	Prof. H. L. Callendar, F.R.S.	Prof. P. V. Bevan, E. Gold, Dr. H. B. Heywood, R. Norrie, Prof. A. W. Porter, W. G. Robson, F. J. M. Stratton.
1913. Birmingham	Dr. H. F. Baker, F.R.S.	Prof. P. V. Bevan, Prof. A. S. Eddington, E. Gold. Dr. H. B. Heywood, Dr. A. O. Rankine, Dr. G. A. Shakespear.

SECTION B.[2]—CHEMISTRY.

Date and Place	Presidents	Secretaries
1901. Glasgow ...	Prof. Percy F. Frankland, F.R.S.	W. C. Anderson, G. G. Henderson, W. J. Pope, T. K. Rose.
1902. Belfast......	Prof. E. Divers, F.R.S..........	R. F. Blake, M. O. Forster, Prof. G. G. Henderson, Prof. W. J. Pope.
1903. Southport	Prof. W. N. Hartley, D.Sc., F.R.S.	Dr. M. O. Forster, Prof. G. G. Henderson, J. Ohm, Prof. W. J. Pope.

[1] Section A was constituted under this title in 1835, when the sectional division was introduced. The previous division was into 'Committees of Sciences.'

[2] 'Chemistry and Mineralogy,' 1835–1891.

Date and Place	Presidents	Secretaries
1904. Cambridge	Prof. Sydney Young, F.R.S....	Dr. M. O. Forster, Prof. G. G. Henderson, Dr. H. O. Jones, Prof. W. J. Pope.
1905. SouthAfrica	George T. Beilby	W. A. Caldecott, Mr. M. O. Forster, Prof. G. G. Henderson, C. F. Juritz.
1906. York.........	Prof. Wyndham R. Dunstan, F.R.S.	Dr. E. F. Armstrong, Prof. A. W. Crossley, S. H. Davies, Prof. W. J. Pope.
1907. Leicester ...	Prof. A. Smithells, F.R.S. ...	Dr. E. F. Armstrong, Prof. A. W. Crossley, J. H. Hawthorn, Dr. F. M. Perkin.
1908. Dublin	Prof. F. S. Kipping, F.R.S....	Dr. E. F. Armstrong, Dr. A. McKenzie, Dr. F. M. Perkin, Dr. J. H. Pollock.
1909. Winnipeg...	Prof. H. E. Armstrong, F.R.S.	Dr. E. F. Armstrong, Dr. T. M. Lowry, Dr. F. M. Perkin, J. W. Shipley.
1910. Sheffield ...	J. E. Stead, F.R.S.	Dr. E. F. Armstrong, Dr. T. M. Lowry, Dr. F. M. Perkin, W. E. S. Turner.
	Sub-section of Agriculture—A D. Hall, F.R.S.	Dr C. Crowther, J. Golding, Dr. E. J. Russell.
1911. Portsmouth	Prof. J. Walker, F R S.	Dr. E. F. Armstrong, Dr. C. H. Desch, Dr. T. M. Lowry, Dr. F. Beddow.
1912. Dundee ...	Prof. A. Senier, M.D	Dr. E. F. Armstrong, Dr. C. H. Desch, Dr. A. Holt, Dr. J. K. Wood.
1913. Birmingham	Prof W. P. Wynne, F.R.S....	Dr. E. F. Armstrong, Dr. C. H. Desch, Dr. A Holt, Dr. H. McCombie.

SECTION C.[3]—GEOLOGY.

1901. Glasgow ...	John Horne, F.R.S.	H. L. Bowman, H. W. Monckton.
1902. Belfast......	Lieut.-Gen. C. A. McMahon, F.R.S.	H. L. Bowman, H. W. Monckton, J. St. J. Phillips, H. J. Seymour.
1903. Southport	Prof. W. W. Watts, M.A., M.Sc.	H. L. Bowman, Rev. W. L. Carter, J. Lomas, H. W. Monckton.
1904. Cambridge	Aubrey Strahan, F.R.S.	H. L. Bowman, Rev. W. L. Carter, J. Lomas, H. Woods.
1905. SouthAfrica	Prof. H. A. Miers, M.A., D.Sc., F.R.S.	H. L. Bowman, J. Lomas, Dr. Molengraaff, Prof. A. Young, Prof. R. B. Young.
1906. York.........	G. W. Lamplugh, F.R.S.	H. L. Bowman, Rev. W. L. Carter, Rev. W. Johnson, J. Lomas.
1907. Leicester...	Prof. J. W. Gregory, F.R.S....	Dr F. W. Bennett, Rev. W. L. Carter, Prof. T. Groom, J. Lomas.
1908. Dublin......	Prof. John Joly, F.R.S.	Rev. W. L. Carter, J. Lomas, Prof. S. H. Reynolds, H. J. Seymour.
1909. Winnipeg...	Dr. A. Smith Woodward, F.R S.	W. L. Carter, Dr. A. R. Dwerryhouse, R. T. Hodgson, Prof. S. H. Reynolds.
1910. Sheffield ...	Prof. A. P. Coleman, F.R.S...	W. L. Carter, Dr. A. R. Dwerryhouse, B Hobson, Prof. S. H. Reynolds.
1911. Portsmouth	A. Harker, F.R.S.	Col. C. W. Bevis, W. L. Carter, Dr. A. R. Dwerryhouse, Prof. S. H. Reynolds.
1912. Dundee ...	Dr. B. N. Peach, F.R.S.	Prof. W. B. Boulton, A. W. R. Don, Dr. A. R. Dwerryhouse, Prof. S. H. Reynolds.
1913. Birmingham	Prof. E. J. Garwood, M.A. ...	Prof. W. S. Boulton, Dr. A. R. Dwerryhouse, F. Raw, Prof. S. H. Reynolds.

[3] 'Geology and Geography,' 1835–1850.

SECTION D.[4]—ZOOLOGY.

Date and Place	Presidents	Secretaries
1901. Glasgow ...	Prof. J. Cossar Ewart, F.R.S.	J. G. Kerr, J. Rankin, J. Y. Simpson.
1902. Belfast......	Prof. G. B. Howes, F.R.S. ...	Prof. J. G. Kerr, R. Patterson, J. Y. Simpson.
1903. Southport	Prof. S. J. Hickson, F.R.S. ...	Dr. J. H. Ashworth, J. Barcroft, A. Quayle, Dr. J. Y. Simpson, Dr. H. W. M. Tims.
1904. Cambridge	William Bateson, F.R.S.	Dr. J. H. Ashworth, L. Doncaster, Prof. J. Y. Simpson, Dr. H. W. M. Tims.
1905. South Africa	G. A. Boulenger, F.R.S.	Dr. Pakes, Dr. Purcell, Dr. H. W. M. Tims, Prof. J. Y. Simpson.
1906. York.........	J. J. Lister, F.R.S.	Dr. J. H. Ashworth, L. Doncaster, Oxley Grabham, Dr. H. W. M. Tims.
1907. Leicester ...	Dr. W. E. Hoyle, M.A.........	Dr. J. H. Ashworth, L. Doncaster, E. E. Lowe, Dr. H. W. M. Tims.
1908. Dublin......	Dr. S. F. Harmer, F.R.S.......	Dr. J. H. Ashworth, L. Doncaster, Prof. A. Fraser, Dr. H. W. M. Tims.
1909. Winnipeg...	Dr. A. E. Shipley, F.R.S. ...	C. A. Baragar, C. L. Boulenger, Dr. J. Pearson, Dr. H. W. M. Tims.
1910. Sheffield ...	Prof. G. C. Bourne, F.R.S. ...	Dr. J. H. Ashworth, L. Doncaster, T. J. Evans, Dr. H. W. M. Tims.
1911. Portsmouth	Prof. D'Arcy W. Thompson, C.B.	Dr. J. H. Ashworth, C. Foran, R. D. Laurie, Dr. H. W. M. Tims.
1912. Dundee ...	Dr. P. Chalmers Mitchell, F.R.S.	Dr. J. H. Ashworth, R. D. Laurie, Miss D. L. Mackinnon, Dr H. W. M. Tims.
1913. Birmingham	Dr. H. F. Gadow, F.R.S	Dr. J. H. Ashworth, Dr. C. L. Boulenger, R. D. Laurie, Dr. H. W. M. Tims.

SECTION E.[5]—GEOGRAPHY.

Date and Place	Presidents	Secretaries
1901. Glasgow ...	Dr. H. R. Mill, F.R.G.S.	H. N. Dickson, E. Heawood, G. Sandeman, A. C. Turner.
1902. Belfast......	Sir T. H. Holdich, K.C.B. ...	G. G. Chisholm, E. Heawood, Dr. A. J. Herbertson, Dr. J. A. Lindsay.
1903. Southport...	Capt. E. W. Creak, R.N., C.B., F.R.S.	E. Heawood, Dr. A. J. Herbertson, E. A. Reeves, Capt. J. C. Underwood.
1904. Cambridge	Douglas W. Freshfield.........	E. Heawood, Dr. A. J. Herbertson, H. Y. Oldham, E. A. Reeves.
1905. South Africa	Adm. Sir W. J. L. Wharton, R.N., K.C.B., F.R.S.	A. H. Cornish-Bowden, F. Flowers, Dr. A. J. Herbertson, H. Y. Oldham.
1906. York.	Rt. Hon. Sir George Goldie, K.C.M.G., F.R.S.	E. Heawood, Dr. A. J. Herbertson, E. A. Reeves, G. Yeld.
1907. Leicester ...	George G. Chisholm, M.A. ...	E. Heawood, O. J. R. Howarth, E. A. Reeves, T. Walker.
1908. Dublin	Major E. H. Hills, C.M.G., R.E.	W. F. Bailey, W. J. Barton, O. J. R. Howarth, E. A. Reeves.

[4] 'Zoology and Botany,' 1835-1847; 'Zoology and Botany, including Physiology,' 1848-1865; 'Biology,' 1866-1894.

[5] Section E was that of 'Anatomy and Medicine,' 1835-1840; of 'Physiology' (afterwards incorporated in Section D), 1841-1847. It was assigned to 'Geography and Ethnology,' 1851-1868; 'Geography,' 1869.

Date and Place	Presidents	Secretaries
1909. Winnipeg...	Col. Sir D. Johnston, K.C.M.G., C.B., R.E.	G. G. Chisholm, J. McFarlane, A. McIntyre.
1910. Sheffield ...	Prof. A. J. Herbertson, M A., Ph.D.	Rev. W. J. Barton, Dr. R. Brown, J. McFarlane, E. A. Reeves.
1911. Portsmouth	Col. C. F. Close, R.E., C.M.G.	J. McFarlane, E. A. Reeves, W. P. Smith.
1912. Dundee ...	Col. Sir C. M. Watson, K.C.M.G.	Rev. W. J. Barton, J. McFarlane, E. A. Reeves, D. Wylie.
1913. Birmingham	Prof. H. N. Dickson, D.Sc. ...	Rev. W. J. Barton, P. E. Martineau, J. McFarlane, E. A. Reeves.

SECTION F.[6]—ECONOMIC SCIENCE AND STATISTICS.

1901. Glasgow ...	Sir R. Giffen, K.C.B., F.R.S.	W. W. Blackie, A. L. Bowley, E. Cannan, S. J. Chapman.
1902. Belfast ...	E. Cannan, M.A., LL.D.	A. L. Bowley, Prof. S. J. Chapman, Dr. A. Duffin.
1903. Southport	E. W. Brabrook, C.B.	A. L. Bowley, Prof. S. J. Chapman, Dr. B. W. Ginsburg, G. Lloyd.
1904. Cambridge	Prof. Wm. Smart, LL.D.	J. E. Bidwell, A. L. Bowley, Prof. S. J. Chapman, Dr. B. W. Ginsburg.
1905. South Africa	Rev. W. Cunningham, D.D., D.Sc.	R. à Ababrelton, A. L. Bowley, Prof. H. E. S. Fremantle, H. O. Meredith.
1906. York.........	A. L. Bowley, M.A.	Prof. S. J. Chapman, D. H. Macgregor, H. O. Meredith, B. S. Rowntree.
1907. Leicester...	Prof. W. J. Ashley, M.A.......	Prof. S. J. Chapman, D. H. Macgregor, H. O. Meredith, T. S. Taylor.
1908. Dublin......	W. M. Acworth, M.A.	W. G. S. Adams, Prof. S. J. Chapman, Prof. D. H. Macgregor, H. O. Meredith
	Sub-section of Agriculture—Rt. Hon. Sir H. Plunkett.	A. D. Hall, Prof. J. Percival, J. H. Priestley, Prof. J. Wilson.
1909. Winnipeg...	Prof. S. J. Chapman, M.A. ...	Prof. A. B. Clark, Dr. W. A. Manahan, Dr. W. R. Scott.
1910. Sheffield ...	Sir H. Llewellyn Smith, K.C.B., M.A.	C. R. Fay, H. O. Meredith, Dr. W. R. Scott, R. Wilson.
1911. Portsmouth	Hon. W. Pember Reeves	C. R. Fay, Dr. W. R. Scott, H. A. Stibbs.
1912. Dundee ...	Sir H. H. Cunynghame, K.C.B.	C. R. Fay, Dr. W. R. Scott, E. Tosh.
1913. Birmingham	Rev. P. H. Wicksteed, M.A.	C. R. Fay, Prof. A. W. Kirkaldy, Prof. H. O. Meredith, Dr. W. R. Scott.

SECTION G.[7]—ENGINEERING.

1901. Glasgow ...	R. E. Crompton, M.Inst.C.E.	H. Bamford, W. E. Dalby, W. A. Price.
1902. Belfast ...	Prof. J. Perry, F.R.S.	M. Barr, W. A. Price, J. Wylie.
1903. Southport	C. Hawksley, M.Inst.C.E. ...	Prof. W. E. Dalby, W. T. Maccall, W. A. Price.
1904. Cambridge	Hon. C. A. Parsons, F.R.S. ...	J. B. Peace, W. T. Maccall, W. A. Price.
1905. South Africa	Col. Sir C. Scott-Moncrieff, G.C.S.I., K.C.M.G., R.E.	W. T. Maccall, W. B. Marshall, Prof. H. Payne, E. Williams.
1906. York.........	J. A. Ewing, F.R.S.	W. T. Maccall, W. A. Price, J. Triffit.
1907. Leicester...	Prof. Silvanus P. Thompson, F.R.S.	Prof. E. G. Coker, A. C. Harris, W. A. Price, H. E. Wimperis.
1908. Dublin......	Dugald Clerk, F.R.S.	Prof. E. G. Coker, Dr. W. E. Lilly, W. A. Price, H. E. Wimperis.

[6] 'Statistics,' 1835-1855. [7] 'Mechanical Science,' 1836-1900.

Date and Place	Presidents	Secretaries
1909. Winnipeg...	Sir W. H. White, K.C.B., F.R.S.	E.E.Brydone-Jack, Prof.E.G.Coker, Prof. E. W. Marchant, W. A. Price.
1910. Sheffield ..	Prof. W. E. Dalby, M.A., M.Inst.C E.	F. Boulden, Prof. E. G. Coker, A. A. Rowse, H. E. Wimperis.
1911. Portsmouth	Prof. J. H. Biles, LL.D., D.Sc.	H. Ashley, Prof. E. G. Coker, A. A. Rowse, H. E. Wimperis.
1912. Dundee ...	Prof. A. Barr, D.Sc.............	Prof. E. G. Coker, A. R. Fulton, H. Richardson, A. A. Rowse, H. E. Wimperis.
1913. Birmingham	Prof. Gisbert Kapp, D.Eng....	Prof. E. G. Coker, J. Purser, A. A. Rowse, H. E. Wimperis.

SECTION H.[8]—ANTHROPOLOGY.

1901. Glasgow ...	Prof. D. J. Cunningham, F.R.S.	W. Crooke, Prof. A. F. Dixon, J. F. Gemmill, J. L. Myres.
1902. Belfast ...	Dr. A. C. Haddon, F.R.S. ...	R. Campbell, Prof. A. F. Dixon, J. L. Myres.
1903. Southport...	Prof. J. Symington, F.R.S....	E. N. Fallaize, H. S. Kingsford, E. M. Littler, J. L. Myres.
1904. Cambridge	H. Balfour, M.A.	W. L. H. Duckworth, E. N. Fallaize, H. S. Kingsford, J. L. Myres.
1905. SouthAfrica	Dr. A. C. Haddon, F.R.S. ...	A. R. Brown, A. von Dessauer, E. S. Hartland.
1906. York.........	E. Sidney Hartland, F.S.A....	Dr. G. A. Auden, E. N. Fallaize, H. S. Kingsford, Dr. F. C. Shrubsall.
1907. Leicester ..	D. G. Hogarth, M.A.............	C. J. Billson, E. N. Fallaize, H. S. Kingsford, Dr. F. C. Shrubsall.
1908. Dublin	Prof. W. Ridgeway, M.A. ...	E. N. Fallaize, H. S. Kingsford, Dr. F. C. Shrubsall, L. E. Steele.
1909. Winnipeg...	Prof. J. L. Myres, M.A.	H. S. Kingsford, Prof. C. J. Patten, Dr. F. C. Shrubsall.
1910. Sheffield ...	W. Crooke, B.A.	E. N. Fallaize, H. S. Kingsford, Prof. C J. Patten, Dr. F. C. Shrubsall.
1911. Portsmouth	W. H. R. Rivers, M.D., F.R.S.	E. N. Fallaize, H. S. Kingsford, E. W. Martindell, H. Rundle, Dr. F. C. Shrubsall.
1912. Dundee ...	Prof. G. Elliot Smith, F.R.S.	D. D. Craig, E. N. Fallaize, E. W. Martindell, Dr. F. C. Shrubsall.
1913. Birmingham	Sir Richard Temple, Bart. ...	E. N. Fallaize, E. W Martindell, Dr. F. C. Shrubsall, T. Yeates.

SECTION I.[9]—PHYSIOLOGY (including Experimental Pathology and Experimental Psychology).

1901. Glasgow ...	Prof. J. G. McKendrick, F.R.S.	W. B. Brodie, W. A. Osborne, Prof. W. H. Thompson.
1902. Belfast ...	Prof. W. D. Halliburton, F.R.S.	J. Barcroft, Dr. W. A. Osborne, Dr. C. Shaw.
1904. Cambridge	Prof. C. S. Sherrington, F.R.S.	J. Barcroft, Prof. T. G. Brodie, Dr. L. E. Shore.
1905. SouthAfrica	Col. D. Bruce, C.B., F.R.S. ...	J. Barcroft, Dr. Baumann, Dr. Mackenzie, Dr. G. W. Robertson, Dr. Stanwell.

[8] Established 1884. [9] Established 1894.

Date and Place	Presidents	Secretaries
1906. York.........	Prof. F. Gotch, F.R.S.	J. Barcroft, Dr. J. M. Hamill, Prof. J. S. Macdonald, Dr. D. S. Long.
1907. Leicester...	Dr. A. D. Waller, F.R.S.	Dr. N. H. Alcock, J. Barcroft, Prof. J. S. Macdonald, Dr. A. Warner.
1908. Dublin......	Dr. J. Scott Haldane, F.R.S.	Prof. D. J. Coffey, Dr. P. T. Herring, Prof. J. S. Macdonald, Dr. H. E. Roaf.
1909. Winnipeg...	Prof. E. H. Starling, F.R S....	Dr. N. H. Alcock, Prof. P. T. Herring, Dr. W. Webster.
1910. Sheffield ...	Prof. A. B. Macallum, F.R.S.	Dr. H. G. M. Henry, Keith Lucas, Dr. H. E. Roaf, Dr. J. Tait.
1911. Portsmouth	Prof. J. S. Macdonald, B.A.	Dr. J. T. Leon, Dr. Keith Lucas, Dr. H. E. Roaf, Dr. J. Tait.
1912. Dundee ...	Leonard Hill, F.R.S.	Dr. Keith Lucas, W. Moodie, Dr. H. E. Roaf, Dr. J. Tait.
1913. Birmingham	Dr. F. Gowland Hopkins, F.R.S.	C. L. Burt, Prof. P. T. Herring, Dr. T. G. Maitland, Dr. H. E. Roaf, Dr. J. Tait.

SECTION K.[10]—BOTANY.

1901. Glasgow ...	Prof. I. B. Balfour, F.R.S. ...	D. T. Gwynne-Vaughan, G. F. Scott-Elliot, A. C. Seward, H. Wager.
1902. Belfast ...	Prof. J. R. Green, F.R S.......	A. G. Tansley, Rev. C. H. Waddell, H. Wager, R. H. Yapp.
1903. Southport	A. C. Seward, F.R.S.	H. Ball, A. G. Tansley, H. Wager, R. H. Yapp.
1904. Cambridge	Francis Darwin, F.R.S. ...... *Sub-section of Agriculture*—Dr. W. Somerville.	Dr. F. F. Blackman, A. G. Tansley, H. Wager, T. B. Wood, R. H. Yapp.
1905. SouthAfrica	Harold Wager, F.R.S.	R. P. Gregory, Dr. Marloth, Prof. Pearson, Prof. R. H. Yapp.
1906. York.........	Prof. F. W. Oliver, F.R.S. ...	Dr. A. Burtt, R. P. Gregory, Prof. A. G. Tansley, Prof. R. H. Yapp.
1907. Leicester...	Prof. J. B. Farmer, F.R.S. ...	W. Bell, R. P. Gregory, Prof. A. G. Tansley, Prof. R. H. Yapp.
1908. Dublin......	Dr. F. F. Blackman, F.R.S....	Prof. H. H. Dixon, R. P. Gregory, A. G. Tansley, Prof. R. H. Yapp.
1909. Winnipeg...	Lieut.-Col. D. Prain, C.I.E., F.R.S.	Prof. A. H. R. Buller, Prof. D. T. Gwynne-Vaughan, Prof. R. H. Yapp.
	Sub-section of Agriculture—Major P. G. Craigie, C.B.	W. J. Black, Dr. E. J. Russell, Prof. J. Wilson.
1910. Sheffield ...	Prof. J. W. H. Trail, F.R.S	B. H. Bentley, R. P. Gregory, Prof. D. T. Gwynne-Vaughan, Prof. R. H. Yapp.
1911. Portsmouth	Prof. F. E. Weiss, D.Sc.	C. G. Delahunt, Prof. D. T. Gwynne-Vaughan, Dr. C. E. Moss, Prof. R. H. Yapp.
	Sub-section of Agriculture—W. Bateson, M.A., F.R.S.	J. Golding, H. R. Pink, Dr. E. J. Russell.
1912. Dundee ...	Prof. F. Keeble, D.Sc..........	J. Brebner, Prof. D. T. Gwynne-Vaughan, Dr. C. E. Moss, D. Thoday.
1913. Birmingham	Miss Ethel Sargant, F.L.S. ..	W. B. Grove, Prof. D. T. Gwynne-Vaughan, Dr. C. E. Moss, D. Thoday.

[10] Established 1895.

SECTION L.—EDUCATIONAL SCIENCE.

Date and Place	Presidents	Secretaries
1901. Glasgow ...	Sir John E. Gorst, F.R.S. ...	R. A. Gregory, W. M. Heller, R. Y. Howie, C. W. Kimmins, Prof. H. L. Withers.
1902. Belfast ...	Prof. H. E. Armstrong, F.R.S.	Prof. R. A. Gregory, W. M. Heller, R. M. Jones, Dr. C. W. Kimmins, Prof. H. L. Withers.
1903. Southport ..	Sir W. de W. Abney, K.C.B., F.R.S.	Prof. R. A. Gregory, W. M. Heller, Dr. C. W. Kimmins, Dr. H. L. Snape.
1904. Cambridge	Bishop of Hereford, D.D. ...	J. H. Flather, Prof. R. A. Gregory, W. M. Heller, Dr. C. W. Kimmins.
1905. SouthAfrica	Prof. Sir R. C. Jebb, D.C.L., M.P.	A. D. Hall, Prof. Hele-Shaw, Dr. C. W. Kimmins, J. R. Whitton.
1906. York.........	Prof. M. E. Sadler, LL.D. ...	Prof. R. A. Gregory, W. M. Heller, Hugh Richardson.
1907. Leicester ...	Sir Philip Magnus, M.P.	W. D. Eggar, Prof. R. A. Gregory, J. S. Laver, Hugh Richardson.
1908. Dublin	Prof. L. C. Miall, F.R.S.	Prof. E. P. Culverwell, W. D. Eggar, George Fletcher, Prof. R. A. Gregory, Hugh Richardson.
1909. Winnipeg...	Rev. H. B. Gray, D.D.	W. D. Eggar, R. Fletcher, J. L. Holland, Hugh Richardson.
1910. Sheffield ...	Principal H. A. Miers, F.R.S.	A. J. Arnold, W. D. Eggar, J. L. Holland, Hugh Richardson.
1911. Portsmouth	Rt. Rev. J. E. C. Welldon, D.D.	W. D. Eggar, O. Freeman, J. L. Holland, Hugh Richardson.
1912. Dundee ...	Prof. J. Adams, M.A.	D. Berridge, Dr. J. Davidson, Prof. J. A. Green, Hugh Richardson.
1913. Birmingham	Principal E. H. Griffiths, F.R.S.	D. Berridge, Rev. S. Blofeld, Prof. J. A. Green, Hugh Richardson.

SECTION M.—AGRICULTURE.

1912. Dundee ...	T. H. Middleton, M.A	Dr. C. Crowther, J. Golding, Dr. A. Lauder, Dr. E. J. Russell.
1913. Birmingham	Prof. T. B. Wood, M.A.	W. E. Collinge, Dr. C. Crowther, J. Golding, Dr. E. J. Russell.

CHAIRMEN AND SECRETARIES OF THE CONFERENCES OF DELEGATES OF CORRESPONDING SOCIETIES, 1901–13.[1]

Date and Place	Chairmen	Secretaries
1901. Glasgow ..	F. W. Rudler, F.G.S.	Dr. J. G. Garson, A. Somerville.
1902 Belfast.....	Prof. W. W. Watts, F.G.S. ...	E. J. Bles.
1903. Southport ..	W. Whitaker, F.R.S.	F. W. Rudler.
1904. Cambridge	Prof. E. H. Griffiths, F.R.S.	F. W. Rudler.
1905. London ...	Dr. A. Smith Woodward, F.R.S.	F. W. Rudler.
1906. York.........	Sir Edward Brabrook, C.B....	F. W. Rudler.
1907. Leicester ...	H. J. Mackinder, M A..........	F. W. Rudler, I S.O.
1908. Dublin	Prof. H. A. Miers, F.R.S.......	W. P. D. Stebbing.
1909. London ...	Dr. A. C. Haddon, F.R.S. ...	W. P. D. Stebbing
1910. Sheffield ...	Dr. Tempest Anderson.........	W. P. D. Stebbing.
1911. Portsmouth	Prof. J. W. Gregory, F.R.S....	W. P. D. Stebbing.
1912. Dundee ...	Prof. F. O. Bower, F.R.S. ...	W. P. D. Stebbing.
1913. Birmingham	Dr. P. Chalmers Mitchell, F.R.S.	W. P. D. Stebbing.

EVENING DISCOURSES, 1901-1913.

Date and Place	Lecturer	Subject of Discourse
1901. Glasgow ...	Prof. W. Ramsay, F.R.S	The Inert Constituents of the Atmosphere.
	Francis Darwin, F.R.S.	The Movements of Plants.
1902. Belfast ...	Prof. J. J. Thomson, F.R.S....	Becquerel Rays and Radio-activity.
	Prof. W. F. R Weldon, F.R.S.	Inheritance.
1903. Southport...	Dr. R. Munro	Man as Artist and Sportsman in the Palæolithic Period.
	Dr. A. Rowe	The Old Chalk Sea, and some of its Teachings.
1904. Cambridge	Prof. G. H. Darwin, F.R.S....	Ripple-Marks and Sand-Dunes.
	Prof. H. F. Osborn	Palæontological Discoveries in the Rocky Mountains.
1905. South Africa:		
Cape Town ...	Prof. E. B. Poulton, F.R.S....	W. J. Burchell's Discoveries in South Africa.
	C. Vernon Boys, F.R.S.	Some Surface Actions of Fluids.
Durban ...	Douglas W. Freshfield.........	The Mountains of the Old World.
	Prof. W. A. Herdman, F.R.S.	Marine Biology.
Pietermaritzburg.	Col. D. Bruce, C.B., F.R.S....	Sleeping Sickness.
	H. T. Ferrar	The Cruise of the 'Discovery.'
Johannesburg	Prof. W. E. Ayrton, F.R.S....	The Distribution of Power.
	Prof. J. O. Arnold..............	Steel as an Igneous Rock.
Pretoria ...	A. E. Shipley, F.R.S.	Fly-borne Diseases: Malaria, Sleeping Sickness, &c.
Bloemfontein...	A. R. Hinks	The Milky Way and the Clouds of Magellan.
Kimberley ...	Sir Wm. Crookes, F.R.S.	Diamonds.
	Prof. J. B. Porter	The Bearing of Engineering on Mining.
Bulawayo ...	D. Randall-MacIver	The Ruins of Rhodesia.

[1] Established 1885.

Date and Place	Lecturer	Subject of Discourse
1906. York.........	Dr. Tempest Anderson.........	Volcanoes.
	Dr. A. D. Waller, F.R.S.	The Electrical Signs of Life, and their Abolition by Chloroform.
1907. Leicester...	W. Duddell, F.R.S.	The Ark and the Spark in Radio-telegraphy.
	Dr. F. A. Dixey..................	Recent Developments in the Theory of Mimicry.
1908. Dublin......	Prof. H. H. Turner, F.R.S. ...	Halley's Comet.
	Prof. W. M. Davis	The Lessons of the Colorado Canyon.
1909. Winnipeg ..	Dr. A. E. H. Tutton, F.R.S...	The Seven Styles of Crystal Architecture.
	Prof. W. A. Herdman, F.R.S.	Our Food from the Waters.
	[1] Prof. H. B. Dixon, F.R.S...	The Chemistry of Flame.
	[1] Prof. J. H. Poynting, F.R.S.	The Pressure of Light.
1910. Sheffield ...	Prof. W. Stirling, M.D.	Types of Animal Movement.[2]
	D. G. Hogarth	New Discoveries about the Hittites.
1911. Portsmouth	Dr. Leonard Hill, F.R.S.......	The Physiology of Submarine Work.
	Prof. A. C. Seward, F.R.S. ...	Links with the Past in the Plant World.
1912. Dundee ...	Prof. W. H. Bragg, F.R.S. ...	Radiations Old and New.
	Prof. A. Keith, M.D.............	The Antiquity of Man.
1913. Birmingham	Sir H. H. Cunynghame, K.C.B.	Explosions in Mines and the Means of Preventing them
	Dr. A. Smith Woodward, F.R.S.	Missing Links among Extinct Animals

[1] 'Popular Lectures,' delivered to the citizens of Winnipeg.
[2] Repeated, to the public, on Wednesday, September 7.

LECTURES TO THE OPERATIVE CLASSES.

Date and Place	Lecturer	Subject of Lecture
1901. Glasgow ...	H. J. Mackinder, M.A..........	The Movements of Men by Land and Sea.
1902. Belfast......	Prof. L. C. Miall, F.R.S.	Gnats and Mosquitoes.
1903. Southport...	Dr. J. S. Flett	Martinique and St. Vincent: the Eruptions of 1902.
1904. Cambridge..	Dr. J. E. Marr, F.R.S.	The Forms of Mountains.
1906. York.........	Prof. S. P. Thompson, F.R.S.	The Manufacture of Light.
1907. Leicester ...	Prof. H. A. Miers, F.R.S.......	The Growth of a Crystal.
1908. Dublin	Dr. A. E. H. Tutton, F.R.S.	The Crystallisation of Water.
1910. Sheffield ...	C. T. Heycock, F.R.S.	Metallic Alloys.
1911. Portsmouth	Dr. H. R. Mill	Rain.

PUBLIC OR CITIZENS' LECTURES.

Date and Place	Lecturer	Subject of Lecture
1912. Dundee ...	Prof. B. Moore, D.Sc.	Science and National Health.
	Prof. E. C. K. Gonner, M.A.	Prices and Wages.
	Prof. A. Fowler, F.R.S.	The Sun.
1913. Birmingham	Dr. A. C. Haddon, F.R.S. ...	The Decorative Art of Savages.
	Dr. Vaughan Cornish	The Panama Canal.
	Leonard Doncaster, M.A. ...	Recent Work on Heredity and its Application to Man.
	Dr. W. Rosenhain, F.R.S. ...	Metals under the Microscope.
	Frederick Soddy, F.R.S.......	The Evolution of Matter.

Table showing the Attendances and Receipts

Date of Meeting	Where held	Presidents	Old Life Members	New Life Members
1831, Sept. 27	York	Viscount Milton, D.C.L., F.R.S.	—	—
1832, June 19	Oxford	The Rev. W. Buckland, F.R.S.	—	—
1833, June 25	Cambridge	The Rev. A. Sedgwick, F.R.S.	—	—
1834, Sept. 8	Edinburgh	Sir T. M. Brisbane, D.C.L., F.R.S.	—	—
1835, Aug. 10	Dublin	The Rev. Provost Lloyd, LL.D., F.R.S.	—	—
1836, Aug. 22	Bristol	The Marquis of Lansdowne, F.R.S.	—	—
1837, Sept. 11	Liverpool	The Earl of Burlington, F.R.S.	—	—
1838, Aug. 10	Newcastle-on-Tyne	The Duke of Northumberland, F.R.S.	—	—
1839, Aug. 26	Birmingham	The Rev. W. Vernon Harcourt, F.R.S.	—	—
1840, Sept. 17	Glasgow	The Marquis of Breadalbane, F.R.S.	—	—
1841, July 20	Plymouth	The Rev. W. Whewell, F.R.S.	169	65
1842, June 23	Manchester	The Lord Francis Egerton, F.G.S.	303	169
1843, Aug. 17	Cork	The Earl of Rosse, F.R.S.	109	28
1844, Sept. 26	York	The Rev. G. Peacock, D.D., F.R.S.	226	150
1845, June 19	Cambridge	Sir John F. W. Herschel, Bart., F.R.S.	313	36
1846, Sept. 10	Southampton	Sir Roderick I. Murchison, Bart., F.R.S.	241	10
1847, June 23	Oxford	Sir Robert H. Inglis, Bart., F.R.S.	314	18
1848, Aug. 9	Swansea	The Marquis of Northampton, Pres. R.S.	149	3
1849, Sept. 12	Birmingham	The Rev. T. R. Robinson, D.D., F.R.S.	227	12
1850, July 21	Edinburgh	Sir David Brewster, K.H., F.R.S.	235	9
1851, July 2	Ipswich	G. B. Airy, Astronomer Royal, F.R.S.	172	8
1852, Sept. 1	Belfast	Lieut.-General Sabine, F.R.S.	164	10
1853, Sept. 3	Hull	William Hopkins, F.R.S.	141	13
1854, Sept. 20	Liverpool	The Earl of Harrowby, F.R.S.	238	23
1855, Sept. 12	Glasgow	The Duke of Argyll, F.R.S.	194	33
1856, Aug. 6	Cheltenham	Prof. C. G. B. Daubeny, M.D., F.R.S.	182	14
1857, Aug. 26	Dublin	The Rev. H. Lloyd, D.D., F.R.S.	236	15
1858, Sept. 22	Leeds	Richard Owen, M.D., D.C.L., F.R.S.	222	42
1859, Sept. 14	Aberdeen	H.R.H. The Prince Consort	184	27
1860, June 27	Oxford	The Lord Wrottesley, M.A., F.R.S.	286	21
1861, Sept. 4	Manchester	William Fairbairn, LL.D., F.R.S.	321	113
1862, Oct. 1	Cambridge	The Rev. Professor Willis, M.A., F.R.S.	239	15
1863, Aug. 26	Newcastle-on-Tyne	Sir William G. Armstrong, C.B., F.R.S.	203	36
1864, Sept. 13	Bath	Sir Charles Lyell, Bart., M.A., F.R.S.	287	40
1865, Sept. 6	Birmingham	Prof. J. Phillips, M.A., LL.D., F.R.S.	292	44
1866, Aug. 22	Nottingham	William R. Grove, Q.C., F.R.S.	207	31
1867, Sept. 4	Dundee	The Duke of Buccleuch, K.C.B., F.R.S.	167	25
1868, Aug. 19	Norwich	Dr. Joseph D. Hooker, F.R.S.	196	18
1869, Aug. 18	Exeter	Prof. G. G. Stokes, D.C.L., F.R.S.	204	21
1870, Sept. 14	Liverpool	Prof. T. H. Huxley, LL.D., F.R.S.	314	39
1871, Aug. 2	Edinburgh	Prof. Sir W. Thomson, LL.D., F.R.S.	246	28
1872, Aug. 14	Brighton	Dr. W. B. Carpenter, F.R.S.	245	36
1873, Sept. 17	Bradford	Prof. A. W. Williamson, F.R.S.	212	27
1874, Aug. 19	Belfast	Prof. J. Tyndall, LL.D., F.R.S.	162	13
1875, Aug. 25	Bristol	Sir John Hawkshaw, F.R.S.	239	36
1876, Sept. 6	Glasgow	Prof. T. Andrews, M.D., F.R.S.	221	35
1877, Aug. 15	Plymouth	Prof. A. Thomson, M.D., F.R.S.	173	19
1878, Aug. 14	Dublin	W. Spottiswoode, M.A., F.R.S.	201	18
1879, Aug. 20	Sheffield	Prof. G. J. Allman, M.D., F.R.S.	184	16
1880, Aug. 25	Swansea	A. C. Ramsay, LL.D., F.R.S.	144	11
1881, Aug. 31	York	Sir John Lubbock, Bart., F.R.S.	272	28
1882, Aug. 23	Southampton	Dr. C. W. Siemens, F.R.S.	178	17
1883, Sept. 19	Southport	Prof. A. Cayley, D.C.L., F.R.S.	203	60
1884, Aug. 27	Montreal	Prof. Lord Rayleigh, F.R.S.	235	20
1885, Sept. 9	Aberdeen	Sir Lyon Playfair, K.C.B., F.R.S.	225	18
1886, Sept. 1	Birmingham	Sir J. W. Dawson, C.M.G., F.R.S.	314	25
1887, Aug. 31	Manchester	Sir H. E. Roscoe, D.C.L., F.R.S.	428	86
1888, Sept. 5	Bath	Sir F. J. Bramwell, F.R.S.	266	36
1889, Sept. 11	Newcastle-on-Tyne	Prof. W. H. Flower, C.B., F.R.S.	277	20
1890, Sept. 3	Leeds	Sir F. A. Abel, C.B., F.R.S.	259	21
1891, Aug. 19	Cardiff	Dr. W. Huggins, F.R.S.	189	24
1892, Aug. 3	Edinburgh	Sir A. Geikie, LL.D., F.R.S.	280	14
1893, Sept. 13	Nottingham	Prof. J. S. Burdon Sanderson, F.R.S.	201	17
1894, Aug. 8	Oxford	The Marquis of Salisbury, K.G., F.R.S.	327	21
1895, Sept. 11	Ipswich	Sir Douglas Galton, K.C.B., F.R.S.	214	13
1896, Sept. 16	Liverpool	Sir Joseph Lister, Bart., Pres. R.S.	330	31
1897, Aug. 18	Toronto	Sir John Evans, K.C.B., F.R.S.	120	8
1898, Sept. 7	Bristol	Sir W. Crookes, F.R.S.	281	19
1899, Sept. 13	Dover	Sir Michael Foster, K.C.B., Sec.R.S.	296	20
1900, Sept. 5	Bradford	Sir William Turner, D.C.L., F.R.S.	267	13

* Ladies were not admitted by purchased tickets until 1843. † Tickets of Admission to Sections only.

[*Continued on p.* xxxiv.

at Annual Meetings of the Association.

Old Annual Members	New Annual Members	Associates	Ladies	Foreigners	Total	Amount received during the Meeting	Sums paid on account of Grants for Scientific Purposes	Year
—	—	—	—	—	353	—	—	1831
—	—	—	—	—	—	—	—	1832
—	—	—	—	—	900	—	—	1833
—	—	—	—	—	1298	—	£20 0 0	1834
—	—	—	—	—	—	—	167 0 0	1835
—	—	—	—	—	1350	—	435 0 0	1836
—	—	—	—	—	1840	—	922 12 6	1837
—	—	—	1100*	—	2400	—	932 2 2	1838
—	—	—	—	34	1438	—	1595 11 0	1839
—	—	—	—	40	1353	—	1546 16 4	1840
46	317	—	60*	—	891	—	1235 10 11	1841
75	376	33†	331*	28	1315	—	1449 17 8	1842
71	185	—	160	—	—	—	1565 10 2	1843
45	190	9†	260	—	—	—	981 12 8	1844
94	22	407	172	35	1079	—	831 9 9	1845
65	39	270	196	36	857	—	685 16 0	1846
197	40	495	203	53	1320	—	208 5 4	1847
54	25	376	197	15	819	£707 0 0	275 1 8	1848
93	33	447	237	22	1071	963 0 0	159 19 6	1849
128	42	510	273	44	1241	1085 0 0	345 18 0	1850
61	47	244	141	37	710	620 0 0	391 9 7	1851
63	60	510	292	9	1108	1085 0 0	304 6 7	1852
56	57	367	236	6	876	903 0 0	205 0 0	1853
121	121	765	524	10	1802	1882 0 0	380 19 7	1854
142	101	1094	543	26	2133	2311 0 0	480 16 4	1855
104	48	412	346	9	1115	1098 0 0	734 13 9	1856
156	120	900	569	26	2022	2015 0 0	507 15 4	1857
111	91	710	509	13	1698	1931 0 0	618 18 2	1858
125	179	1206	821	22	2564	2782 0 0	684 11 1	1859
177	59	636	463	47	1689	1604 0 0	766 19 6	1860
184	125	1589	791	15	3138	3944 0 0	1111 5 10	1861
150	57	433	242	25	1161	1089 0 0	1293 16 6	1862
154	209	1704	1004	25	3335	3640 0 0	1608 3 10	1863
182	103	1119	1058	13	2802	2965 0 0	1289 15 8	1864
215	149	766	508	23	1997	2227 0 0	1591 7 10	1865
218	105	960	771	11	2303	2469 0 0	1750 13 4	1866
193	118	1163	771	7	2444	2613 0 0	1739 4 0	1867
226	117	720	682	45‡	2004	2042 0 0	1940 0 0	1868
229	107	678	600	17	1856	1931 0 0	1622 0 0	1869
303	195	1103	910	14	2878	3096 0 0	1572 0 0	1870
311	127	976	754	21	2463	2575 0 0	1472 2 6	1871
280	80	937	912	43	2533	2649 0 0	1285 0 0	1872
237	99	796	601	11	1983	2120 0 0	1685 0 0	1873
232	85	817	630	12	1951	1979 0 0	1151 16 0	1874
307	93	884	672	17	2248	2397 0 0	960 0 0	1875
331	185	1265	712	25	2774	3023 0 0	1092 4 2	1876
238	59	446	283	11	1229	1268 0 0	1128 9 7	1877
290	93	1285	674	17	2578	2615 0 0	725 16 6	1878
239	74	529	349	13	1404	1425 0 0	1080 11 11	1879
171	41	389	147	12	915	899 0 0	731 7 7	1880
313	176	1230	514	24	2557	2689 0 0	476 8 1	1881
253	79	516	189	21	1253	1286 0 0	1126 1 11	1882
330	323	952	841	5	2714	3369 0 0	1083 3 3	1883
317	219	826	74	26 & 60 H.§	1777	1855 0 0	1173 4 0	1884
332	122	1053	447	6	2203	2256 0 0	1385 0 0	1885
428	179	1067	429	11	2453	2532 0 0	995 0 6	1886
510	244	1985	493	92	3838	4336 0 0	1186 18 0	1887
399	100	639	509	12	1984	2107 0 0	1511 0 5	1888
412	113	1024	579	21	2437	2441 0 0	1417 0 11	1889
368	92	680	334	12	1775	1776 0 0	789 16 8	1890
341	152	672	107	35	1497	1664 0 0	1029 10 0	1891
413	141	733	439	50	2070	2007 0 0	864 10 0	1892
328	57	773	268	17	1661	1653 0 0	907 15 6	1893
435	69	941	451	77	2321	2175 0 0	583 15 6	1894
290	31	493	261	22	1324	1236 0 0	977 15 5	1895
383	139	1384	873	41	3181	3228 0 0	1104 6 1	1896
286	125	682	100	41	1362	1398 0 0	1059 10 8	1897
327	96	1051	639	33	2446	2399 0 0	1212 0 0	1898
324	68	548	120	27	1403	1328 0 0	1430 14 2	1899
297	45	801	482	9	1915	1801 0 0	1072 10 0	1900

‡ Including Ladies. § Fellows of the American Association were admitted as Hon. Members for this Meeting.

[*Continued on p.* xxxv.

Table showing the Attendances and Receipts

Date of Meeting	Where held	Presidents	Old Life Members	New Life Members
1901, Sept. 11	Glasgow	Prof. A. W. Rücker, D.Sc., Sec.R.S.	310	37
1902, Sept. 10	Belfast	Prof. J. Dewar, LL.D., F.R.S.	243	21
1903, Sept. 9	Southport	Sir Norman Lockyer, K.C.B., F.R.S.	250	21
1904, Aug. 17	Cambridge	Rt. Hon. A. J. Balfour, M.P., F.R.S.	419	32
1905, Aug. 15	South Africa	Prof. G. H. Darwin, LL.D., F.R.S.	115	40
1906, Aug. 1	York	Prof. E. Ray Lankester, LL.D., F.R.S.	322	10
1907, July 31	Leicester	Sir David Gill, K.C.B., F.R.S.	276	19
1908, Sept. 2	Dublin	Dr. Francis Darwin, F.R.S.	294	24
1909, Aug. 25	Winnipeg	Prof. Sir J. J. Thomson, F.R.S.	117	13
1910, Aug. 31	Sheffield	Rev. Prof. T. G. Bonney, F.R.S.	293	26
1911, Aug. 30	Portsmouth	Prof. Sir W. Ramsay, K.C.B., F.R.S.	284	21
1912, Sept. 4	Dundee	Prof. E. A. Schäfer, F.R.S.	288	14
1913, Sept. 10	Birmingham	Sir Oliver J. Lodge, F.R.S.	376	40

¶ Including 848 Members of the South African Association.

ANALYSIS OF ATTENDANCES AT

[*The total attendances for the years* 1832,

Average attendance at 79 *Meetings* : 1858.

	Average Attendance
Average attendance at 5 Meetings beginning during *June, between* 1833 *and* 1860	1260
Average attendance at 4 Meetings beginning during *July, between* 1841 *and* 1907	1122
Average attendance at 32 Meetings beginning during *August, between* 1836 *and* 1911	1927
Average attendance at 37 Meetings beginning during *September, between* 1831 *and* 1913	1977
Attendance at 1 Meeting held in *October, Cambridge*, 1862	1161

Meetings beginning during August.

Average attendance at—

4 Meetings beginning during the 1st week in *August* (1st–7th)	1905
5 ,, ,, ,, ,, 2nd ,, ,, ,, (8th–14th)	2130
9 ,, ,, ,, ,, 3rd ,, ,, ,, (15th–21st)	1802
14 ,, ,, ,, ,, 4th ,, ,, ,, (22nd–31st)	1935

at Annual Meetings of the Association—(continued).

Old Annual Members	New Annual Members	Associates	Ladies	Foreigners	Total	Amount received during the Meeting	Sums paid on account of Grants for Scientific Purposes	Year
374	131	794	246	20	1912	£2046 0 0	£920 9 11	1901
314	86	647	305	6	1620	1644 0 0	947 0 0	1902
319	90	688	365	21	1754	1762 0 0	845 13 2	1903
449	113	1338	317	121	2789	2650 0 0	887 18 11	1904
937¶	411	430	181	16	2130	2122 0 0	928 2 2	1905
356	93	817	352	22	1972	1811 0 0	882 0 9	1906
339	61	659	251	42	1647	1561 0 0	757 12 10	1907
465	112	1166	222	14	2297	2317 0 0	1157 18 8	1908
290**	162	789	90	7	1468	1623 0 0	1014 9 9	1909
379	57	563	123	8	1449	1439 0 0	963 17 0	1910
349	61	414	81	31	1241	1176 0 0	922 0 0	1911
368	95	1292	359	88	2504	2349 0 0	845 7 6	1912
480	149	1287	291	20	2643	2756 0 0	978 17 1	1913

** Including 137 Members of the American Association.

THE ANNUAL MEETINGS, 1831-1913.

1835, 1843, *and* 1844 *are unknown.*]

Meetings beginning during September.

Average attendance at—

		Average Attendance
13 Meetings beginning during the 1st week in *September*	(1st– 7th).	2131
17 „ „ „ „ 2nd „ „ „	(8th–14th).	1906
5 „ „ „ „ 3rd „ „ „	(15th–21st).	2206
2 „ „ „ „ 4th „ „ „	(22nd–30th).	1025

Meetings beginning during June, July, and October.

Attendance at 1 Meeting (1845, June 19) beginning during the 3rd week in *June* (15th–21st) 1079

Average attendance at 4 Meetings beginning during the 4th week in *June* (22nd–30th) 1306

Attendance at 1 Meeting (1851, July 2) beginning during the 1st week in *July* (1st–7th) 710

Average attendance at 2 Meetings beginning during the 3rd week in *July* (15th–21st) 1066

Attendance at 1 Meeting (1907, July 31) beginning during the 5th week in *July* (29th–31st) 1647

Attendance at 1 Meeting (1862, October 1) beginning during the 1st week in *October* (1st–7th) 1161

General Statement of Sums which have been paid on account of Grants for Scientific Purposes, 1901-1912.

1901.

	£	s.	d.
Electrical Standards	45	0	0
Seismological Observations	75	0	0
Wave-length Tables	4	14	0
Isomorphous Sulphonic Derivatives of Benzene	35	0	0
Life-zones in British Carboniferous Rocks	20	0	0
Underground Water of North-west Yorkshire	50	0	0
Exploration of Irish Caves	15	0	0
Table at the Zoological Station, Naples	100	0	0
Table at the Biological Laboratory, Plymouth	20	0	0
Index Generum et Specierum Animalium	75	0	0
Migration of Birds	10	0	0
Terrestrial Surface Waves	5	0	0
Changes of Land-level in the Phlegræan Fields	50	0	0
Legislation regulating Women's Labour	15	0	0
Small Screw Gauge	45	0	0
Resistance of Road Vehicles to Traction	75	0	0
Silchester Excavation	10	0	0
Ethnological Survey of Canada	30	0	0
Anthropological Teaching	5	0	0
Exploration in Crete	145	0	0
Physiological Effects of Peptone	30	0	0
Chemistry of Bone Marrow	5	15	11
Suprarenal Capsules in the Rabbit	5	0	0
Fertilisation in Phæophyceæ	15	0	0
Morphology, Ecology, and Taxonomy of Podostemaceæ	20	0	0
Corresponding Societies Committee	15	0	0
	£920	9	11

1902.

	£	s.	d.
Electrical Standards	40	0	0
Seismological Observations	35	0	0
Investigation of the Upper Atmosphere by means of Kites	75	0	0
Magnetic Observations at Falmouth	80	0	0
Relation between Absorption Spectra and Organic Substances	20	0	0
Wave-length Tables	5	0	0
Life-zones in British Carboniferous Rocks	10	0	0
Exploration of Irish Caves	45	0	0
Table at the Zoological Station, Naples	100	0	0
Index Generum et Specierum Animalium	100	0	0
Migration of Birds	15	0	0
Structure of Coral Reefs of Indian Ocean	50	0	0
Compound Ascidians of the Clyde Area	25	0	0
Terrestrial Surface Waves	15	0	0
Legislation regulating Women's Labour	30	0	0
Small Screw Gauge	20	0	0
Resistance of Road Vehicles to Traction	50	0	0
Ethnological Survey of Canada	15	0	0
Age of Stone Circles	30	0	0
Exploration in Crete	100	0	0
Anthropometric Investigation of Native Egyptian Soldiers	15	0	0
Excavations on the Roman Site at Gelligaer	5	0	0
Changes in Hæmoglobin	15	0	0
Work of Mammalian Heart under Influence of Drugs	20	0	0
Investigation of the Cyanophyceæ	10	0	0
Reciprocal Influence of Universities and Schools	5	0	0
Conditions of Health essential to carrying on Work in Schools	2	0	0
Corresponding Societies Committee	15	0	0
	£947	0	0

1903.

	£	s.	d.
Electrical Standards	35	0	0
Seismological Observations	40	0	0
Investigation of the Upper Atmosphere by means of Kites	75	0	0
Magnetic Observations at Falmouth	40	0	0
Study of Hydro-aromatic Substances	20	0	0
Erratic Blocks	10	0	0
Exploration of Irish Caves	40	0	0
Underground Waters of North-west Yorkshire	40	0	0

	£	s.	d.
Life-zones in British Carboniferous Rocks	5	0	0
Geological Photographs	10	0	0
Table at the Zoological Station at Naples	100	0	0
Index Generum et Specierum Animalium	100	0	0
Tidal Bore, Sea Waves, and Beaches	15	0	0
Scottish National Antarctic Expedition	50	0	0
Legislation affecting Women's Labour	25	0	0
Researches in Crete	100	0	0
Age of Stone Circles	3	13	2
Anthropometric Investigation	5	0	0
Anthropometry of the Todas and other Tribes of Southern India	50	0	0
The State of Solution of Proteids	20	0	0
Investigation of the Cyanophyceæ	25	0	0
Respiration of Plants	12	0	0
Conditions of Health essential for School Instruction	5	0	0
Corresponding Societies Committee	20	0	0
	£845	13	2

1904.

	£	s.	d.
Seismological Observations	40	0	0
Investigation of the Upper Atmosphere by means of Kites	50	0	0
Magnetic Observations at Falmouth	60	0	0
Wave-length Tables of Spectra	10	0	0
Study of Hydro-aromatic Substances	25	0	0
Erratic Blocks	10	0	0
Life-zones in British Carboniferous Rocks	35	0	0
Fauna and Flora of the Trias	10	0	0
Investigation of Fossiliferous Drifts	50	0	0
Table at the Zoological Station, Naples	100	0	0
Index Generum et Specierum Animalium	60	0	0
Development in the Frog	15	0	0
Researches on the Higher Crustacea	15	0	0
British and Foreign Statistics of International Trade	25	0	0
Resistance of Road Vehicles to Traction	90	0	0
Researches in Crete	100	0	0
Researches in Glastonbury Lake Village	25	0	0
Anthropometric Investigation of Egyptian Troops	8	10	0
Excavations on Roman Sites in Britain	25	0	0
The State of Solution of Proteids	20	0	0
Metabolism of Individual Tissues	40	0	0
Botanical Photographs	4	8	11
Respiration of Plants	15	0	0
Experimental Studies in Heredity	35	0	0
Corresponding Societies Committee	20	0	0
	£887	18	11

1905.

	£	s.	d.
Electrical Standards	40	0	0
Seismological Observations	40	0	0
Investigation of the Upper Atmosphere by means of Kites	40	0	0
Magnetic Observations at Falmouth	50	0	0
Wave-length Tables of Spectra	5	0	0
Study of Hydro-aromatic Substances	25	0	0
Dynamic Isomerism	20	0	0
Aromatic Nitroamines	25	0	0
Fauna and Flora of the British Trias	10	0	0
Table at the Zoological Station, Naples	100	0	0
Index Generum et Specierum Animalium	75	0	0
Development of the Frog	10	0	0
Investigations in the Indian Ocean	150	0	0
Trade Statistics	4	4	8
Researches in Crete	75	0	0
Anthropometric Investigations of Egyptian Troops	10	0	0
Excavations on Roman Sites in Britain	10	0	0
Anthropometric Investigations	10	0	0
Age of Stone Circles	30	0	0
The State of Solution of Proteids	20	0	0
Metabolism of Individual Tissues	30	0	0
Ductless Glands	40	0	0
Botanical Photographs	3	17	6
Physiology of Heredity	35	0	0
Structure of Fossil Plants	50	0	0
Corresponding Societies Committee	20	0	0
	£928	2	2

1906.

	£	s.	d.
Electrical Standards	25	0	0
Seismological Observations	40	0	0
Magnetic Observations at Falmouth	50	0	0
Magnetic Survey of South Africa	99	12	6
Wave-length Tables of Spectra	5	0	0
Study of Hydro-aromatic Substances	25	0	0
Aromatic Nitroamines	10	0	0
Fauna and Flora of the British Trias	7	8	11
Crystalline Rocks of Anglesey	30	0	0
Table at the Zoological Station, Naples	100	0	0
Index Animalium	75	0	0
Development of the Frog	10	0	0
Higher Crustacea	15	0	0
Freshwater Fishes of South Africa	50	0	0
Rainfall and Lake and River Discharge	10	0	0
Excavations in Crete	100	0	0
Lake Village at Glastonbury	40	0	0
Excavations on Roman Sites in Britain	30	0	0
Anthropometric Investigations in the British Isles	30	0	0
State of Solution of Proteids	20	0	0
Metabolism of Individual Tissues	20	0	0
Effect of Climate upon Health and Disease	20	0	0
Research on South African Cycads	14	19	4
Peat Moss Deposits	25	0	0
Studies suitable for Elementary Schools	5	0	0
Corresponding Societies Committee	25	0	0
	£882	0	9

1907.

	£	s.	d.
Electrical Standards	50	0	0
Seismological Observations	40	0	0
Magnetic Observations at Falmouth	40	0	0
Magnetic Survey of South Africa	25	7	6
Wave-length Tables of Spectra	10	0	0
Study of Hydro-aromatic Substances	30	0	0
Dynamic Isomerism	30	0	0
Life Zones in British Carboniferous Rocks	10	0	0
Erratic Blocks	10	0	0
Fauna and Flora of British Trias	10	0	0
Faunal Succession in the Carboniferous Limestone of South-West England	15	0	0
Correlation and Age of South African Strata, &c.	10	0	0
Table at the Zoological Station, Naples	100	0	0
Index Animalium	75	0	0
Development of the Sexual Cells	1	11	8
Oscillations of the Land Level in the Mediterranean Basin	50	0	0
Gold Coinage in Circulation in the United Kingdom	8	19	7
Anthropometric Investigations in the British Isles	10	0	0
Metabolism of Individual Tissues	45	0	0
The Ductless Glands	25	0	0
Effect of Climate upon Health and Disease	55	0	0
Physiology of Heredity	30	0	0
Research on South African Cycads	35	0	0
Botanical Photographs	5	0	0
Structure of Fossil Plants	5	0	0
Marsh Vegetation	15	0	0
Corresponding Societies Committee	16	14	1
	£757	12	10

1908.

	£	s.	d.
Seismological Observations	40	0	0
Further Tabulation of Bessel Functions	15	0	0
Investigation of Upper Atmosphere by means of Kites	25	0	0
Meteorological Observations on Ben Nevis	25	0	0
Geodetic Arc in Africa	200	0	0
Wave-length Tables of Spectra	10	0	0
Study of Hydro-aromatic Substances	30	0	0
Dynamic Isomerism	40	0	0
Transformation of Aromatic Nitroamines	30	0	0
Erratic Blocks	17	16	6
Fauna and Flora of British Trias	10	0	0
Faunal Succession in the Carboniferous Limestone in the British Isles	10	0	0
Pre-Devonian Rocks	10	0	0
Exact Significance of Local Terms	5	0	0
Composition of Charnwood Rocks	10	0	0
Table at the Zoological Station at Naples	100	0	0
Index Animalium	75	0	0
Hereditary Experiments	10	0	0
Fauna of Lakes of Central Tasmania	40	0	0
Investigations in the Indian Ocean	50	0	0

	£	s.	d.
Exploration in Spitsbergen ...	30	0	0
Gold Coinage in Circulation in the United Kingdom......	3	7	6
Electrical Standards	50	0	0
Glastonbury Lake Village ...	30	0	0
Excavations on Roman Sites in Britain	15	0	0
Age of Stone Circles...	50	0	0
Anthropological Notes and Queries	40	0	0
Metabolism of Individual Tissues..........................	40	0	0
The Ductless Glands...........	13	14	8
Effect of Climate upon Health and Disease.....................	35	0	0
Body Metabolism in Cancer...	30	0	0
Electrical Phenomena and Metabolism of *Arum Spadices*	10	0	0
Marsh Vegetation	15	0	0
Succession of Plant Remains	18	0	0
Corresponding Societies Committee	25	0	0
	£1157	18	8

1909.

	£	s.	d.
Seismological Observations ..	60	0	0
Investigation of the Upper Atmosphere by means of Kites	10	0	0
Magnetic Observations at Falmouth	50	0	0
Establishing a Solar Observatory in Australia	50	0	0
Wave-length Tables of Spectra	9	16	0
Study of Hydro-aromatic Substances	15	0	0
Dynamic Isomerism...........	35	0	0
Transformation of Aromatic Nitroamines	10	0	0
Electroanalysis	30	0	0
Fauna and Flora of British Trias	8	0	0
Faunal Succession in the Carboniferous Limestone in the British Isles	8	0	0
Palæozoic Rocks of Wales and the West of England	9	0	0
Igneous and Associated Sedimentary Rocks of Glensaul	11	13	9
Investigations at Biskra	50	0	0
Table at the Zoological Station at Naples	100	0	0
Heredity Experiments.........	10	0	0
Feeding Habits of British Birds	5	0	0
Index Animalium..............	75	0	0
Investigations in the Indian Ocean	35	0	0
Gaseous Explosions	75	0	0
Excavations on Roman Sites in Britain	5	0	0
Age of Stone Circles...........	30	0	0
Researches in Crete	70	0	0
The Ductless Glands	35	0	0
Electrical Phenomena and Metabolism of *Arum Spadices*	10	0	0
Reflex Muscular Rhythm......	10	0	0
Anæsthetics	25	0	0
Mental and Muscular Fatigue	27	0	0
Structure of Fossil Plants ...	5	0	0
Botanical Photographs.........	10	0	0
Experimental Study of Heredity........................	30	0	0
Symbiosis between Turbellarian Worms and Algæ	10	0	0
Survey of Clare Island.........	65	0	0
Curricula of Secondary Schools	5	0	0
Corresponding Societies Committee	21	0	0
	£1014	9	9

1910.

	£	s.	d.
Measurement of Geodetic Arc in South Africa............ ..	100	0	0
Republication of Electrical Standards Reports	100	0	0
Seismological Observations...	60	0	0
Magnetic Observations at Falmouth	25	0	0
Investigation of the Upper Atmosphere	25	0	0
Study of Hydro-aromatic Substances	25	0	0
Dynamic Isomerism...........	35	0	0
Transformation of Aromatic Nitroamines	15	0	0
Electroanalysis	10	0	0
Faunal Succession in the Carboniferous Limestone in the British Isles	10	0	0
South African Strata	5	0	0
Fossils of Midland Coalfields	25	0	0
Table at the Zoological Station at Naples	100	0	0
Index Animalium	75	0	0
Heredity Experiments	15	0	0
Feeding Habits of British Birds	5	0	0
Amount and Distribution of Income	15	0	0
Gaseous Explosions	75	0	0
Lake Villages in the neighbourhood of Glastonbury...	5	0	0
Excavations on Roman Sites in Britain	5	0	0
Neolithic Sites in Northern Greece......	5	0	0
The Ductless Glands	40	0	0
Body Metabolism in Cancer...	20	0	0
Anæsthetics	25	0	0
Tissue Metabolism	25	0	0
Mental and Muscular Fatigue	18	17	0
Electromotive Phenomena in Plants	10	0	0

	£	s.	d.
Structure of Fossil Plants ...	10	0	0
Experimental Study of Heredity	30	0	0
Survey of Clare Island	30	0	0
Corresponding Societies Committee	20	0	0
	£963	17	0

1911.

	£	s.	d.
Seismological Investigations	60	0	0
Magnetic Observations at Falmouth	25	0	0
Investigation of the Upper Atmosphere	25	0	0
Grant to International Commission on Physical and Chemical Constants	30	0	0
Study of Hydro-aromatic Substances	20	0	0
Dynamic Isomerism	25	0	0
Transformation of Aromatic Nitroamines	15	0	0
Electroanalysis	15	0	0
Influence of Carbon, &c., on Corrosion of Steel	15	0	0
Crystalline Rocks of Anglesey	2	0	0
Mammalian Fauna in Miocene Deposits, Bugti Hills, Baluchistan	75	0	0
Table at the Zoological Station at Naples	100	0	0
Index Animalium	75	0	0
Feeding Habits of British Birds	5	0	0
Belmullet Whaling Station	30	0	0
Map of Prince Charles Foreland	30	0	0
Gaseous Explosions	90	0	0
Lake Villages in the neighbourhood of Glastonbury	5	0	0
Age of Stone Circles	30	0	0
Artificial Islands in Highland Lochs	10	0	0
The Ductless Glands	40	0	0
Anæsthetics	20	0	0
Mental and Muscular Fatigue	25	0	0
Electromotive Phenomena in Plants	10	0	0
Dissociation of Oxy-Hæmoglobin	25	0	0
Structure of Fossil Plants ...	15	0	0
Experimental Study of Heredity	45	0	0
Survey of Clare Island	20	0	0
Registration of Botanical Photographs	10	0	0
Mental and Physical Factors involved in Education	10	0	0
Corresponding Societies Committee	20	0	0
	£922	0	0

1912.

	£	s.	d.
Seismological Investigations	60	0	0
Magnetic Observations at Falmouth	25	0	0
Investigation of the Upper Atmosphere	30	0	0
Grant to International Commission on Physical and Chemical Constants	30	0	0
Further Tabulation of Bessel Functions	15	0	0
Study of Hydro-aromatic Substances	20	0	0
Dynamic Isomerism	30	0	0
Transformation of Aromatic Nitroamines	10	0	0
Electroanalysis	10	0	0
Study of Plant Enzymes	30	0	0
Erratic Blocks	5	0	0
Igneous and Associated Rocks of Glensaul, &c.	15	0	0
List of Characteristic Fossils	5	0	0
Sutton Bone Bed	15	0	0
Bembridge Limestone at Creechbarrow Hill	20	0	0
Table at the Zoological Station at Naples	50	0	0
Index Animalium	75	0	0
Belmullet Whaling Station	20	0	0
Secondary Sexual Characters in Birds	10	0	0
Gaseous Explosions	60	0	0
Lake Villages in the neighbourhood of Glastonbury	5	0	0
Artificial Islands in Highland Lochs	10	0	0
Physical Character of Ancient Egyptians	40	0	0
Excavation in Easter Island	15	0	0
The Ductless Glands	35	0	0
Calorimetric Observations on Man	40	0	0
Structure of Fossil Plants ...	15	0	0
Experimental Study of Heredity	35	0	0
Survey of Clare Island	20	0	0
Jurassic Flora of Yorkshire	15	0	0
Overlapping between Secondary and Higher Education	1	18	6
Curricula, &c., of Industrial and Poor Law Schools	10	0	0
Influence of School Books upon Eyesight	3	9	0
Corresponding Societies Committee	25	0	0
Collections illustrating Natural History of Isle of Wight	40	0	0
	£845	7	6

REPORT OF THE COUNCIL, 1912-13.

I. The Council have to record their profound sorrow at the death of Sir William H. White, K.C.B., F.R.S., President-Elect. A resolution expressing their deep sympathy with the members of his family was conveyed to Lady White by the President.

The Association was represented at the funeral by Professor E. A. Schäfer, President, Major P. A. MacMahon, General Secretary, and a number of Members of the Council and others.

II. A Resolution expressing the Council's sympathy and deep sense of loss at the death of Sir George Darwin, F.R.S., ex-President, was conveyed to the members of his family; and the Association was represented at the funeral by Major P. A. MacMahon, General Secretary.

III. A Resolution expressing the Council's regret and sympathy at the death of the Rt. Hon. Lord Avebury, F.R.S., ex-President and Trustee of the Association, was conveyed to the members of his family.

IV. Sir H. A. Miers, F.R.S., was appointed to represent the Association at the International Geological Congress at Toronto in August, 1913.

V. Professor W. Bateson, F.R.S., has been unanimously nominated by the Council to fill the office of President of the Association for 1914-15 (Australian Meeting).

VI. (*a*) The arrangements for the Australian Meeting have occupied the attention of a Committee appointed by the Council to assist the President and General Officers, and are progressing favourably. Draft programmes have been prepared, furnishing details of the arrangements proposed.

(*b*) The Council have considered what alterations, if any, it may be necessary to make in the transaction of business at the Australian meeting in consequence of the exceptional distance. They recommend that the General Committee hold only two meetings in Australia (following the precedent of previous oversea meetings), and are of opinion that it will probably be found most convenient to hold these at Adelaide and Brisbane, the Committee of Recommendations being held at Sydney during the intervening period: they further recommend that a third meeting of the General Committee should be held in London, after the Australian meeting, if necessary for the consideration of outstanding business.

(*c*) The Committee appointed to advise the Council in respect of any action to be taken in connection with the proposed exploration in Oceania in 1914 was authorised to approach the Secretary to the Admiralty, and subsequently the Federal Government through the High Commissioner for Australia, on behalf of the Council, and negotiations and inquiries are proceeding.

(*d*) A letter has been received from Dr. A. Loir, of Havre, Local Secretary for the Meeting of the French Association for the Advancement of Science in Havre in 1914, intimating that the municipality of Havre desires to invite as guests leading Members of the British Association who do not

attend the meeting in Australia, and that all Members not attending that meeting will be welcomed at the meeting of the French Association; also proposing that the Conference of Delegates should meet in Havre. Information has also been received from Dr. Loir that a Local Committee, including some of the principal British residents in Havre, has been formed for the reception of Members of the British Association.

It was resolved that the invitation be cordially accepted, in general terms, and that details of the arrangements be left to the consideration of the President and General Officers and a committee appointed to assist them.

(*e*) The attention of the Council has been drawn to the question of relaxing for the year 1914 (Australian Meeting) the rule under which Annual Members intermitting their subscriptions for one year lose thereafter the right to receive the Annual Report free. This question was referred by the General Committee at Sheffield to the consideration of the Council.

The Council have resolved to report that they are unable to support the proposal to relax this rule.

VII. (*a*) The Council, having considered the question of the disposa of Sir J. K. Caird's gift of 10,000*l.* to the Association, have resolved to recommend:—

> That the income remain in the hands of the Council under the name of 'The Caird Fund'; and be available for allocation by the Council at any time for special scientific purposes. The Council are also of opinion that further consideration might be given hereafter to the question as to whether the capital or a part thereof should be spent on some special scheme or schemes.

(*b*) The following memorial, to which were appended the signatures of an influential body of biologists, sixty-nine in number, has been received:—

> 'The biologists whose names are subscribed desire to call the attention of the Council to the urgent importance of the maintenance of a table at the Zoological station at Naples for the use of British subjects. They consider that it is very desirable that the table which has for many years been known as the "British Association Table" should be given a permanent endowment, so that its maintenance should no longer depend upon the vote in the Committee of Recommendations at the yearly meetings of the Association. The Zoology Organisation Committee will be pleased to appoint a small deputation of biologists to wait upon the Council to discuss the arrangements that should be made.'

The Council, in consideration of the interest on Sir J. K. Caird's gift accumulating during the present year, authorised the payment of 50*l.* to the Committee appointed to aid investigators to carry on work at the Zoological Station at Naples, in addition to the grant made to the Committee at the Dundee Meeting.

VIII. RESOLUTIONS referred to the Council by the General Committee at Dundee:—

From Section A.

'That it is desirable that a detailed Magnetic Survey of the British Isles, on the lines of that of Professors Rücker and Thorpe for

the epoch of 1891, should now be repeated, in order to answer the question as to the local variations of the terrestrial magnetic elements within twenty-five years.

'That a representation to this effect be made to the Royal Society, the Admiralty, the Ordnance Survey, and the Meteorological Committee.

'That having regard to the importance of the observations at Falmouth in the work of the previous Survey and in other work in connection with terrestrial magnetism and meteorology, steps be taken to assist an appeal for a Treasury grant, in order that the Observatory at Falmouth may be efficiently maintained.'

The Council appointed a Committee to consider and report on any necessary steps in connection with the above proposals. The Committee was subsequently empowered to act as might be necessary, and resolved that its report be communicated to the Royal Society, as it was understood that the Society already had the matter under consideration. The Committee's report is as follows:—

I.

The Committee is of opinion that it is desirable to repeat without delay the Magnetic Survey of the British Isles carried out under the auspices of the Royal Society between the years 1886-96; and further considers that the approximate number of stations for the fundamental survey should be about 200, and that about 50 more will be wanted for testing the permanence of the position of one of the chief ridge lines. It is estimated that such a survey could be carried out for a sum of, approximately, 1,000*l*.

The Committee recommends that the British Association make a substantial contribution towards this sum.

II.

While the Committee attaches importance to the existence of a station in the south-west, it was of opinion that if the Survey were carried through rapidly the maintenance of the observations at the Falmouth Observatory would not be essential. After consideration and enquiry it was unable to recommend that steps be taken to assist an appeal for a Treasury grant, in order that the Observatory might be maintained.

From Section D.

'That the British Association for the Advancement of Science deplores the rapid destruction of fauna and flora throughout the world, and regards it as an urgent duty that immediate steps should be taken to secure the preservation of all species of animals and plants irrespective of their economic or sporting value.'

The Council approved the principle of the above Resolution, and resolved to give expression to it in the following terms:—

'That the British Association for the Advancement of Science deplores the rapid destruction of fauna and flora throughout the world, and regards it as an urgent duty that steps should be taken, by the

formation of suitably placed reserves, or otherwise, to secure the preservation of examples of all species of animals and plants, irrespective of their economic or sporting value, except in cases where it has been clearly proved that the preservation of particular organisms, even in restricted numbers, and places, is a menace to human welfare.'

From Section H.

'That the copies of the fourth edition of *Notes and Queries in Anthropology*, now on the point of publication through the Committee appointed for the purpose of its preparation, be delivered as heretofore to the Royal Anthropological Institute for sale to its members and to the public; the proceeds to be reserved at the disposal of the Association towards the expenses of any future editions, and accounts of the sales to be submitted to the General Treasurer of the Association on demand.'

The Council resolved to confirm the arrangements proposed in the above resolution, and further (*a*) that members of the Association and Fellows of the Royal Anthropological Institute may obtain copies at 3*s*. 6*d*. each (the price to the public being 5*s*.); (*b*) that the President of the Royal Anthropological Institute may occasionally present copies to workers who in his opinion are likely to make good use of them.

IX. The following NOMINATIONS are made by the Council:—

Conference of Delegates.—Dr. P. Chalmers Mitchell (*Chairman*), Sir H. G. Fordham (*Vice-Chairman*), Mr. W. P. D. Stebbing (*Secretary*).

Corresponding Societies Committee.—Mr. W. Whitaker (*Chairman*), Mr. W. P. D. Stebbing (*Secretary*), Rev. J. O. Bevan, Sir Edward Brabrook, Sir H. G. Fordham, Dr. J. G. Garson, Principal E. H. Griffiths, Dr. A. C. Haddon, Mr. T. V. Holmes, Mr. J. Hopkinson, Mr. A. L. Lewis, Rev. T. R. R. Stebbing, Mr. W. Mark Webb, and the President and General Officers of the Association.

X. The Council have received reports from the General Treasurer during the past year. His ACCOUNTS from July 1, 1912, to June 30, 1913, have been audited and are presented to the General Committee.

XI. The retiring members of the Council are:—

Sir Oliver J. Lodge (on becoming a member *ex-officio* and President for the year); Mr. E. Sidney Hartland and Dr. P. Chalmers Mitchell (by seniority); Dr. Tempest Anderson and Sir Lauder Brunton (resigned during the year).

The Council have nominated the following new members:—

Prof. W. H. Bragg,
Dr. F. A. Dixey,
Mr. Alfred Lodge,

leaving two vacancies to be filled by the General Committee without nomination by the Council.

The full list of nominations of ordinary members is as follows :—

Prof. H. E. Armstrong.
Sir E. Brabrook.
Prof. W. H. Bragg.
Dr. Dugald Clerk.
Major P. G. Craigie.
W. Crooke.
Prof. A. Dendy.
Dr. F. A. Dixey.
Prof. J. B. Farmer.
Principal E. H. Griffiths.
Dr. A. C. Haddon.
A. D. Hall.
Prof. W. D. Halliburton.
Capt. H. G. Lyons.
Alfred Lodge.
Dr. J. E. Marr.
Prof. R. Meldola.
Prof. J. L. Myres.
Sir D. Prain.
Prof. C. S. Sherrington.
J. J. H. Teall.
Prof. S. P. Thompson.
Prof. F. T. Trouton.

XII. Major P. A. MacMahon has been nominated by the Council as a TRUSTEE of the Association in succession to the late Lord Avebury.

XIII. The GENERAL OFFICERS have been nominated by the Council as follows :—

General Treasurer : Prof. J. Perry.

General Secretaries : Prof. W. A. Herdman.
Prof. H. H. Turner.

The Council have received with great regret Major P. A. MacMahon's intimation of his intention to resign the office of General Secretary at the Birmingham Meeting.

XIV. The following have been admitted as members of the General Committee :—

Mrs. E. A. Newell Arber.
Dr. T. Ashby.
Dr. Henry Bassett.
Miss M. J. Benson.
Sidney G. Brown.
F. Balfour Browne.
Dr. W. S. Bruce.
Miss Florence Buchanan.
E. R. Burdon.
W. Lower Carter.
Prof. F. J. Cole.
Dr. W. Cramer.
Major H. A. Cummins.
Dr. O. V. Darbishire.
J. Burtt Davy.
Prof. H. H. Dixon.
Prof. W. E. Dixon.
W. G. Fearnsides.
H. T. Ferrar.
Dr. F. E. Fritsch.
Dr. R. R. Gates.
Dr. J. F. Gemmil.
R. P. Gregory.
Prof. D. T. Gwynne-Vaughan.
Dr. H. S. Harrison.
Prof. J. P. Hill.
Prof. G. W. O. Howe.
Dr. A. A. Lawson.
Dr. R. Marloth.
Prof. A. Meek.
Dr. S. R. Milner.
Prof. B. Moore.
Sir F. W. Moore.
W. M. Mordey.
Dr. C. E. Moss.
Prof. T. G. B. Osborn.
Prof. H. H. W. Pearson.
Prof. R. W. Phillips.
Prof. A. W. Porter.
R. Lloyd Praeger.
Dr. W. Rosenhain.
Miss E. R. Saunders.
Dr. S. Schönland.
R. E. Slade.
Miss A. Lorrain Smith.
Dr. O. Stapf.
W. Stiles.
Dr. Marie C. Stopes.
D. Thoday.
Prof. A. H. Trow.
Dr. E. W. Ainley Walker.
Miss E. J. Welsford.
Prof. G. S. West.
Dr. J. C. Willis.
Prof. R. H. Yapp.

Dr. THE GENERAL TREASURER IN ACCOUNT ADVANCEMENT OF SCIENCE,

1912–1913. RECEIPTS.

	£	s.	d.	£	s.	d.
Balance brought forward				229	15	9
Life Compositions (including Transfers)				356	0	0
New Annual Members' Subscriptions				286	0	0
Annual Subscriptions				642	0	0
Sale of Associates' Tickets				1,262	0	0
Sale of Ladies' Tickets				357	0	0
Sale of Publications				203	0	11
Sale of Great Indian Peninsula Railway 'B' Annuity				617	8	6
Sir James Caird's Gift				10,000	0	0
Interest on temporary investment thereof				75	11	1
Interest on Deposit at Dundee Bank				39	1	6
Unexpended Balances of Grants returned:						
Belmullet Whaling Station	6	2	9			
Gaseous Explosions	15	0	0			
Solar Observatory in Australia	50	0	0			
				71	2	9
Income Tax returned				55	12	4
Dividend on Consols				134	4	8
Dividend on India 3 per Cent. Stock				101	14	0
Dividend on Great Indian Peninsula Railway 'B' Annuity				39	3	4
Dividend on India 3½ per Cent. Stock, 'Caird Fund'				21	12	11
Dividend on London and North-Western Railway Consolidated 4 per Cent. Preference Stock, 'Caird Fund'				47	1	8
Dividend on London and South-Western Railway Consolidated 4 per Cent. Preference Stock, 'Caird Fund'				47	1	8

Mem.: Receipts on account of the Birmingham Meeting (1913) amounting to £84. 10*s.* 4*d.*, are not included in this Account, but are paid to a Separate (No. 2) Account at the Bank.

Investments.

Nominal Amount £	s.	d.		Value at 30th June, 1913. £	s.	d.
5,701	10	5	2½ per Cent. Consolidated Stock	4,169	4	9
3,600	0	0	India 3 per Cent. Stock	2,700	0	0
879	14	9	£43 Great Indian Peninsula Railway 'B' Annuity (cost)	827	15	0
2,627	0	10	India 3½ per Cent. Stock, 'Caird Fund'	2,285	10	6
2,500	0	0	London and North-Western Railway 4 per Cent. Preference Stock, 'Caird Fund'	2,525	0	0
2,500	0	0	Canada 3½ per Cent. 1930–1950 Registered Stock, 'Caird Fund'	2,325	0	0
2,500	0	0	London and South-Western Railway 4 per Cent. Consolidated Preference Stock, 'Caird Fund'	2,475	0	0
			Sir Frederick Bramwell's Gift:—			
76	1	3	2½ per Cent. Self-cumulating Consolidated Stock.			

£14,585 11 1

[To be awarded in 1931 for a paper dealing with the whole question of the prime movers of 1931, and especially with the then relation between steam engines and internal combustion engines.]

JOHN PERRY, *General Treasurer.*

WITH THE BRITISH ASSOCIATION FOR THE *Cr.*

July 1, 1912, to June 30, 1913.

1912–1913. PAYMENTS.

	£	s.	d.	£	s.	d.
Rent and Office Expenses				169	6	3
Salaries, &c.				695	7	5
Printing, Binding, &c.				1,078	11	7
Expenses of Dundee Meeting				232	2	0
Purchase of Stock				10,000	0	0
Kelvin Memorial Volume				55	13	6
Grants to Research Committees:—						
Seismological Investigations	60	0	0			
Investigation of the Upper Atmosphere	50	0	0			
Grant to International Commission on Physical and Chemical Constants	40	0	0			
Further Tabulation of Bessel Functions	30	0	0			
Study of Hydro-aromatic Substances	20	0	0			
Dynamic Isomerism	30	0	0			
Transformation of Aromatic Nitroamines	20	0	0			
Study of Plant Enzymes	30	0	0			
Igneous and Associated Rocks of Glensaul, &c.	10	0	0			
List of Characteristic Fossils	5	0	0			
Exploration of the Upper Old Red Sandstone of Dura Den	75	0	0			
Geology of Ramsey Island	10	0	0			
Old Red Sandstone Rocks of Kiltorcan	15	0	0			
Table at the Zoological Station at Naples	50	0	0			
Ditto ditto (Special Grant)	50	0	0			
Nomenclature Animalium Genera et Sub-genera	100	0	0			
Belmullet Whaling Station	15	0	0			
Ditto (Special Grant)	10	0	0			
Gaseous Explosions	80	0	0			
Lake Villages in the neighbourhood of Glastonbury	5	0	0			
Age of Stone Circles (Special Grant)	15	0	0			
Artificial Islands in the Highlands of Scotland	5	0	0			
Excavations on Roman Sites in Britain	15	0	0			
Hansa Manuscripts	20	0	0			
Ductless Glands	40	0	0			
Calorimetric Observations on Man	45	0	0			
Dissociation of Oxy-Hæmoglobin at High Altitudes	15	0	0			
Structure and Function of the Mammalian Heart	20	0	0			
Structure of Fossil Plants	15	0	0			
Jurassic Flora of Yorkshire	4	12	4			
Vegetation of Ditcham Park, Hampshire	45	0	0			
Influence of School Books on Eyesight	9	4	9			
Corresponding Societies Committee	25	0	0			
				978	17	1

	£	s.	d.	£	s.	d.	£	s.	d.
Balance at Bank of Scotland, Dundee (including accrued Interest)				1,156	4	4			
Balance at Bank of England (Western Branch), including £191 7*s.* 4*d.* Income from the Caird Fund	£327	3	0						
Cash not paid in	2	0	0						
	329	3	0						
Less Cheques not presented	110	18	9						
				218	4	3			
Petty Cash in hand				1	4	8			
							1,375	13	3
							£14,585	11	1

An Account of about £910 is outstanding due to Messrs. Spottiswoode & Co.

I have examined the above Account with the Books and Vouchers of the Association, and certify the same to be correct. I have also verified the Balance at the Bankers, and have ascertained that the Investments are registered in the names of the Trustees.

W. B. KEEN, *Chartered Accountant.*
23 Queen Victoria Street, E.C.
July 31, 1913.

Approved—
EDWARD BRABROOK, } *Auditor*
HERBERT MCLEOD, }

GENERAL MEETINGS AT BIRMINGHAM.

On Wednesday, September 10, at 8.30 P.M., in the Central Hall, a communication was read from Sir E. A. Schafer, F.R.S., who was unavoidably absent, resigning the office of President to Sir Oliver J. Lodge, F.R.S., who took the Chair and delivered an Address, for which see p. 3.

On Thursday, September 11, at 8.30 P.M., the Lord Mayor held a Reception and Conversazione in the Council House and Art Gallery.

On Friday, September 12, at 8.30 P.M., in the Central Hall, Sir H. H. Cunynghame, K.C.B., delivered a Discourse on 'Explosions in Mines and the means of preventing them.'

On Monday, September 15, Evening Entertainments were given by the Local Committee in the Prince of Wales' Theatre (Opera), the Repertory Theatre, and the Picture House.

On Tuesday, September 16, in the Central Hall, Dr. A. Smith Woodward, F.R.S., delivered a Discourse on 'Missing Links among Extinct Animals.'

On Wednesday, September 17, at 3 P.M., the concluding General Meeting was held in the Midland Institute, when the following Resolutions were adopted :—

1. That the cordial thanks of the Association be given to the Right Hon. the Lord Mayor and Corporation of the City of Birmingham for the hearty welcome accorded to this Meeting, and to the citizens for their generous hospitality.

2. That a cordial vote of thanks be extended to the governing bodies of the University of Birmingham and other Institutions for their kindness in placing their buildings and resources at the disposal of the Association.

3. That a cordial vote of thanks be extended to the ladies and gentlemen who, in the kindest manner, gave themselves personal trouble in the reception of members of the Association, both in connection with excursions and also private garden parties and other receptions ; and to the firms which generously threw open their works to members of the Association.

4. That a cordial vote of thanks be given to the Honorary Local Officers, to the Executive Committees, and to the members of the General Committee for the admirable arrangements made for the Meeting.

OFFICERS OF SECTIONAL COMMITTEES PRESENT AT THE BIRMINGHAM MEETING.

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCE.*

President.—Dr. H. F. Baker, F.R.S. *Vice-Presidents.*—Prof. R. S. Heath, D.Sc. ; Prof. E. W. Hobson, F.R.S. ; Prof. J. H. Poynting, F.R.S. ; R. Threlfall, F.R.S. ; Prof. A. W. Porter, F.R.S. ; Prof. H. H. Turner, F.R.S. *Secretaries.*—Prof. P. V. Bevan, Sc.D. (*Recorder*) ; Prof. A. S. Eddington, M.Sc. ; E. Gold, M.A. ; Dr. H. B. Heywood ; Dr. A. O. Rankine ; Dr. G. A. Shakespear.

* The name of Prof. J. E. A. Steggall was omitted in error from the list of Vice-presidents of this Section in the Report of the Dundee Meeting, 1912.

SECTION B.—CHEMISTRY.

President.—Prof. W. P. Wynne, F.R.S. *Vice-Presidents.*—Prof. Adrian J. Brown, F.R.S.; Madame Curie; Prof. P. Frankland, F.R.S.; Prof. A. Senier, M.D.; Prof. T. Turner. *Secretaries.*—Dr. E. F. Armstrong (*Recorder*); Dr. C. H. Desch; Dr. A. Holt; Dr. Hamilton McCombie.

SECTION C.—GEOLOGY.

President.—Prof. E. J. Garwood, M.A. *Vice-Presidents.*—George Barrow; Prof. T. G. Bonney, F.R.S.; Prof. J. Cadman, D.Sc.; Dr. Victor Goldschmidt; Prof. Chas. Lapworth, F.R.S. *Secretaries.*—Dr. A. R. Dwerryhouse (*Recorder*); Prof. W. S. Boulton, D.Sc.; Prof. S. H. Reynolds; F. Raw, B.Sc.

SECTION D.—ZOOLOGY.

President.—Dr. H. F. Gadow, F.R.S. *Vice-Presidents.*—G. T. Bethune-Baker; Dr. F. A. Dixey, F.R.S.; Prof. Louis Dollo; Prof. F. W. Gamble, F.R.S.; Prof. F. Keibel; Dr. P. Chalmers Mitchell, F.R.S. *Secretaries.*—Dr. H. W. Marett Tims (*Recorder*); Dr. J. H. Ashworth; Dr. C. L. Boulenger; R. Douglas Laurie, M.A.

SECTION E.—GEOGRAPHY.

President.—Prof. H. N. Dickson, D.Sc. *Vice-Presidents.*—Dr. W. S. Bruce; G. G. Chisholm, M.A.; Col. C. F. Close, C.M.G.; Dr. J. Scott Keltie; Sir C. P. Lucas, K.C.M.G.; Capt. H. G. Lyons, F.R.S. *Secretaries.*—Rev. W. J. Barton, M.A. (*Recorder*); J. McFarlane, M.A.; P. E. Martineau; E. A. Reeves.

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

President.—Rev. P. H. Wicksteed, M.A. *Vice-Presidents.*—Prof. W. J. Ashley, M.A.; Dr. A. L. Bowley, M.A.; Prof. E. Cannan, LL.D.; Neville Chamberlain; Sir H. H. Cunynghame, K.C.B. *Secretaries.*—Dr. W. R. Scott (*Recorder*); C. R. Fay, M.A.; Prof. A. W. Kirkaldy, M.A.; Prof. H. O. Meredith, M.A.

SECTION G.—ENGINEERING.

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SECTION H.—ANTHROPOLOGY.

President.—Sir Richard Temple, Bart., C.I.E. *Vice-Presidents.*—Dr. G. A. Auden, M.A.; Sir Everard im Thurn, K.C.M.G.; Prof. G. Elliot Smith, F.R.S.; Prof. E. A. Sonnenschein; Prof. P. Thompson, M.D. *Secretaries.*—E. N. Fallaize (*Recorder*); E. W. Martindell, M.A.; Dr. F. C. Shrubsall; T. Yeates, M.B.

SECTION I.—PHYSIOLOGY.

President.—Dr. F. Gowland Hopkins, F.R.S. *Vice-Presidents.*—Prof. E. W. Wace Carlier, M.D.; Dr. W. H. Gaskell, F.R.S.; Prof. Leonard Hill, F.R.S.; Prof. R. F. C. Leith, M.A.; Prof. J. H. Muirhead, LL.D. *Secretaries.*—Dr. H. E. Roaf (*Recorder*); C. L. Burt, M.A.; Prof. P. T. Herring, M.D.; Dr. T. G. Maitland; Dr. J. Tait.

SECTION K.—BOTANY.

President.—Miss Ethel Sargant, F.L.S. *Vice-Presidents.*—Prof. F. Keeble, F.R.S.; Prof. F. W. Oliver, F.R.S.; Sir David Prain, C.M.G., F.R.S.; Dr. D. H. Scott, F.R.S.; Prof. A. C. Seward, F.R.S.; Prof. G. E. West, D.Sc.; Prof. R. H. Yapp, M.A. *Secretaries.*—Prof. D. T. Gwynne-Vaughan, M.A. (*Recorder*); W. B. Grove, M.A.; Dr. C. E. Moss; D. Thoday, M.A.

SECTION L.—EDUCATIONAL SCIENCE.

President.—Principal E. H. Griffiths, F.R.S. *Vice-Presidents.*—R. Cary Gilson, M.A.; Sir A. Hopkinson; Prof. A. Hughes, M.A.; Sir G. H. Kenrick; A. Mosely, C.M.G. *Secretaries.*—Prof. J. A. Green (*Recorder*); D. Berridge, M.A.; Rev. S. Blofeld, B.A.; H. Richardson, M.A.

SECTION M.—AGRICULTURE.

President.—Prof. T. B. Wood, M.A. *Vice-Presidents.*—Prof. W. Bateson, F.R.S.; A. D. Hall, F.R.S.; T. H. Middleton, C.B.; Prof. W. Somerville, M.A. *Secretaries.*—Dr. E. J. Russell (*Recorder*); W. E. Collinge, M.Sc.; Dr. C. Crowther; J. Golding.

CONFERENCE OF DELEGATES OF CORRESPONDING SOCIETIES.

Chairman.—Dr. P. Chalmers Mitchell, F.R.S. *Vice-Chairman.*—Sir H. G. Fordham. *Secretary.*—W. P. D. Stebbing.

COMMITTEE OF RECOMMENDATIONS.

The President and Vice-Presidents of the Association; the General Secretaries; the General Treasurer; the Trustees; the Presidents of the Association in former years; the Chairman of the Conference of Delegates; Dr. F. H. Baker; Prof. H. H. Turner; Prof. W. P. Wynne; Dr. E. F. Armstrong; Prof. E. J. Garwood; Dr. A. R. Dwerryhouse; Dr. H. F. Gadow; Dr. Marett Tims; Prof. H. N. Dickson; Rev. W. J. Barton; Rev. P. H. Wicksteed; Dr. W. R. Scott; Prof. Gisbert Kapp; Prof. E. G. Coker; Sir R. C. Temple; E. N. Fallaize; Dr. F. Gowland Hopkins; Dr. H. E. Roaf; Miss E. Sargant; Prof. D. T. Gwynne-Vaughan; Principal E. H. Griffiths; Prof. J. A. Green; Prof. T. B. Wood; Dr. E. J. Russell; Sir H. G. Fordham.

LIST OF GRANTS: Birmingham, 1913.

Research Committees, etc., appointed by the General Committee at the Birmingham Meeting: September 1913.

1. *Receiving Grants of Money.*

Subject for Investigation, or Purpose	Members of Committee	Grants
	Section A.—MATHEMATICS AND PHYSICS.	
		£ s. d.
Seismological Observations.	*Chairman.*—Professor H. H. Turner. *Secretary.*—Professor J. Perry. Mr. Horace Darwin, Dr. R. T. Glazebrook, Mr. M. H. Gray, Mr. R. K. Gray, Professors J. W. Judd and C. G. Knott, Sir J. Larmor, Professor R. Meldola, Mr. W. E. Plummer, Dr. R. A. Sampson, Professor A. Schuster, Mr. J. J. Shaw, and Mr. G. W. Walker.	60 0 0*
Investigation of the Upper Atmosphere.	*Chairman.*—Dr. W. N. Shaw. *Secretary.*—Mr. E. Gold. Mr. D. Archibald, Mr. C. J. P. Cave, Mr. W. H. Dines, Dr. R. T. Glazebrook, Sir J. Larmor, Professor J. E. Petavel, Dr. A. Schuster, and Dr. W. Watson.	25 0 0
Annual Tables of Constants and Numerical Data, chemical, physical, and technological.	*Chairman.*—Sir W. Ramsay. *Secretary.*—Dr. W. C. McC. Lewis.	40 0 0
Calculation of Mathematical Tables.	*Chairman.*—Professor M. J. M. Hill. *Secretary.*—Professor J. W. Nicholson. Mr. J. R. Airey, Professor Alfred Lodge, Professor L. N. G. Filon, Sir G. Greenhill, and Professors E. W. Hobson, A. E. H. Love, H. M. Macdonald, and A. G. Webster.	20 0 0
Disposing of Copies of the 'Binary Canon' by presentation to Mathematical Societies.	*Chairman.*—Lieut.-Col. A. Cunningham. *Secretary.*—Professor A. E. H. Love. Major P. A. MacMahon.	5 0 0

* In addition, the Council was authorised to expend a sum not exceeding £70 for the printing of circulars, etc., in connection with the Committee on Seismological Observations. See also Caird Fund, p. lxvi.

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants
	Section B.—CHEMISTRY.	
		£ s. d.
The Study of Hydro-aromatic Substances.	*Chairman.*—Professor W. H. Perkin. *Secretary.*—Professor A. W. Crossley. Dr. M. O. Forster, Dr. Le Sueur, and Dr. A. McKenzie.	15 0 0
Dynamic Isomerism.	*Chairman.*—Professor H. E. Armstrong. *Secretary.*—Dr. T. M Lowry. Professor Sydney Young, Dr. Desch, Dr. J. J. Dobbie, and Dr. M. O. Forster.	25 0 0
The Transformation of Aromatic Nitroamines and allied substances, and its relation to Substitution in Benzene Derivatives.	*Chairman.*—Professor F. S. Kipping. *Secretary.*—Professor K. J. P. Orton. Dr. S. Ruhemann and Dr. J. T. Hewitt.	15 0 0
The Study of Plant Enzymes, particularly with relation to Oxidation.	*Chairman.*—Mr. A. D. Hall. *Secretary.*—Dr. E. F. Armstrong. Professor H. E. Armstrong, Professor F. Keeble, and Dr. E. J. Russell.	25 0 0
Correlation of Crystalline Form with Molecular Structure.	*Chairman.*—Professor W. J. Pope. *Secretary.*—Professor H E. Armstrong. Mr. W. Barlow and Professor W. P. Wynne.	25 0 0
Study of Solubility Phenomena.	*Chairman.*—Professor H. E. Armstrong. *Secretary.*—Dr. J. V. Eyre. Dr. E. F. Armstrong, Professor A. Findlay, Dr. T. M. Lowry, and Professor W. J. Pope.	15 0 0
	Section C.—GEOLOGY.	
To investigate the Erratic Blocks of the British Isles, and to take measures for their preservation.	*Chairman.*—Mr. R. H. Tiddeman. *Secretary.*—Dr. A. R. Dwerryhouse. Dr. T. G. Bonney, Mr. F. W. Harmer, Rev. S. N. Harrison, Dr. J. Horne, Mr. W. Lower Carter, Professor W. J. Sollas, and Messrs. W. Hill, J. W. Stather, and J. H. Milton.	5 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants
		£ s. d.
To consider the preparation of a List of Characteristic Fossils.	*Chairman.*—Professor P. F. Kendall. *Secretary.*—Mr. W. Lower Carter. Mr. H. A. Allen, Professor W. S. Boulton, Professor G. Cole, Dr. A. R. Dwerryhouse, Professors J. W. Gregory, Sir T. H. Holland, G. A. Lebour, and S. H. Reynolds, Dr. Marie C. Stopes, Mr. Cosmo Johns, Dr. J. E. Marr, Dr. A. Vaughan, Professor W. W. Watts, Mr. H. Woods, and Dr. A. Smith Woodward.	5 0 0
The Geology of Ramsay Island, Pembrokeshire.	*Chairman.*—Dr. A. Strahan. *Secretary.*—Mr. H. H. Thomas. Mr. E. E. L. Dixon, Dr. J. W. Evans, and Professor O. T. Jones.	10 0 0
The Old Red Sandstone Rocks of Kiltorcan, Ireland.	*Chairman.*—Professor Grenville Cole. *Secretary.*—Professor T. Johnson. Dr. J. W. Evans, Dr. R. Kidston, and Dr. A. Smith Woodward.	10 0 0
Fauna and Flora of the Trias of the Western Midlands.	*Chairman.*—Mr. G. Barrow. *Secretary.*—Mr. L. J. Wills. Dr. J. Humphreys, Mr. W. Campbell Smith, Mr. D. S. Watson, and Professor W. W. Watts.	10 0 0
To excavate Critical Sections in the Lower Palæozoic Rocks of England and Wales.	*Chairman.* — Professor W. W. Watts. *Secretary.* — Professor W. G. Fearnsides. Professor W. S. Boulton, Mr. E. S. Cobbold, Mr. V. C. Illing, Dr. Lapworth, and Dr. J. E. Marr.	15 0 0

SECTION D.—ZOOLOGY.

To investigate the Biological Problems incidental to the Belmullet Whaling Station.	*Chairman.*—Dr. A. E. Shipley. *Secretary.*—Professor J. Stanley Gardiner. Professor W. A. Herdman, Rev. W. Spotswood Green, Mr. E. S. Goodrich, Dr. H. W. Marett Tims, and Mr. R. M. Barrington.	20 0 0
Nomenclator Animalium Genera et Sub-genera.	*Chairman.*—Dr. Chalmers Mitchell. *Secretary.*—Rev. T. R. R. Stebbing. Dr. M. Laurie, Dr. Marett Tims, and Dr. A. Smith Woodward.	50 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants
		£ s. d.
To provide assistance for Major G. E. H. Barrett-Hamilton's Expedition to South Georgia to investigate the position of the Antarctic Whaling Industry.	*Chairman.*—Dr. S. F. Harmer. *Secretary.*—Dr. W. T. Calman. Dr. Bather, Dr. W. S. Bruce, and Dr. P. Chalmers Mitchell.	90 0 0
	SECTION E.—GEOGRAPHY.	
To inquire into the choice and style of Atlas, Textual, and Wall Maps for School and University Use.	*Chairman.*—Professor J. L. Myres. *Secretary.*—Rev. W. J. Barton. Professors R. L Archer and R. N. R. Brown, Mr. G. G. Chisholm, Col. C. F. Close, Professor H. N. Dickson, Mr. A. R. Hinks, Mr. O. J. R. Howarth, Sir Duncan Johnston, and Mr. E. A. Reeves.	40 0 0
Strengths and Directions of Tidal Currents in the Moray Firth and adjacent firths.	*Chairman.*—Dr. H. N. Dickson. *Secretary.*—Mr. A. G. Ogilvie. Dr. J. Horne and Dr. J. S. Owens.	40 0 0
	SECTION G.—ENGINEERING.	
The Investigation of Gaseous Explosions, with special reference to Temperature.	*Chairman.*—Sir W. H. Preece. *Vice-Chairman.*—Dr. Dugald Clerk. *Secretary.*—Professor W. E. Dalby. Professors W. A. Bone, F. W. Burstall, H. L. Callendar, E. G. Coker, and H. B. Dixon, Drs. R. T. Glazebrook and J. A. Harker, Colonel H. C. L. Holden, Professors B. Hopkinson and J. E. Petavel, Captain H. Riall Sankey, Professor A. Smithells, Professor W. Watson, Mr. D. L. Chapman, and Mr. H. E. Wimperis.	50 0 0
To report on certain of the more complex Stress Distributions in Engineering Materials.	*Chairman.*—Professor J. Perry. *Secretaries.* — Professors E. G. Coker and J. E. Petavel. Professor A. Barr, Dr. Chas. Chree, Mr. Gilbert Cook, Professor W. E. Dalby, Sir J. A. Ewing, Professor L. N. G. Filon, Messrs. A. R. Fulton and J. J. Guest, Professors J. B. Henderson and A. E. H. Love, Mr. W. Mason, Sir Andrew Noble, Messrs. F. Rogers and W. A. Scoble, Dr. T. E. Stanton, and Mr. J. S. Wilson.	50 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants
SECTION H.—ANTHROPOLOGY.		£ s. d.
To investigate the Lake Villages in the neighbourhood of Glastonbury in connection with a Committee of the Somerset Archæological and Natural History Society.	*Chairman.*—Professor Boyd Dawkins. *Secretary.*—Mr. Willoughby Gardner. Professor W. Ridgeway, Sir Arthur J. Evans, Sir C. H. Read, Mr. H. Balfour, and Dr. A. Bulleid.	20 0 0
To conduct Explorations with the object of ascertaining the Age of Stone Circles.	*Chairman.*—Sir C. H. Read. *Secretary.*—Mr. H. Balfour. Dr. G. A. Auden, Professor W. Ridgeway, Dr. J. G. Garson, Sir A. J. Evans, Dr. R. Munro, Professors Boyd Dawkins and J. L. Myres, Mr. A. L. Lewis, and Mr. H. Peake.	20 0 0
To investigate and ascertain the Distribution of Artificial Islands in the lochs of the Highlands of Scotland.	*Chairman.*—Professor Boyd Dawkins. *Secretary.*—Mr. A. J. B. Wace. Professors T. H. Bryce, W. Boyd Dawkins, J. L. Myres, and W. Ridgeway.	5 0 0
To investigate the Physical Characters of the Ancient Egyptians.	*Chairman.*—Professor G. Elliot Smith. *Secretary.*—Dr. F. C. Shrubsall. Dr. F. Wood-Jones, Dr. A. Keith, and Dr. C. G. Seligmann.	34 16 6
To co-operate with Local Committees in Excavations on Roman Sites in Britain.	*Chairman.*—Professor W. Ridgeway. *Secretary.*—Professor R. C. Bosanquet. Dr. T. Ashby, Mr. Willoughby Gardner, and Professor J. L. Myres.	20 0 0
To conduct Anthropometric Investigations in the Island of Cyprus.	*Chairman.*—Professor J. L. Myres. *Secretary.*—Dr. F. C. Shrubsall. Dr. A. C. Haddon.	50 0 0
To excavate a Palæolithic Site in Jersey.	*Chairman.*—Dr. R. R. Marett. *Secretary.*—Col. Warton. Dr. C. W. Andrews, Dr. Dunlop, Mr. G. de Gruchy, and Professor A. Keith.	50 0 0
SECTION I.—PHYSIOLOGY.		
The Ductless Glands.	*Chairman.*—Sir E. A. Schäfer. *Secretary.*—Professor Swale Vincent. Professor A. B. Macallum, Dr. L. E. Shore, and Mrs. W. H. Thompson.	35 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants
		£ s. d.
To acquire further knowledge, Clinical and Experimental, concerning Anæsthetics—general and local—with special reference to Deaths by or during Anæsthesia, and their possible diminution.	*Chairman.*—Dr. A. D. Waller. *Secretary.*—Sir F. W. Hewitt. Dr. Blumfeld, Mr. J. A. Gardner, and Dr. G. A. Buckmaster.	20 0 0
Calorimetric Observations on Man in Health and in Febrile Conditions.	*Chairman.*—Professor J. S. Macdonald. *Secretary.*—Dr. Francis A. Duffield. Dr. Keith Lucas.	40 0 0
Further Researches on the Structure and Function of the Mammalian Heart.	*Chairman.*—Professor C. S. Sherrington. *Secretary.*—Professor Stanley Kent.	30 0 0
The Binocular Combination of Kinematograph Pictures of different Meaning, and its relation to the Binocular Combination of simpler Perceptions.	*Chairman.*—Dr. C. S. Myers. *Secretary.*—T. H. Pear.	10 0 0

Section K.—BOTANY.

Subject for Investigation, or Purpose	Members of Committee	Grants
The Structure of Fossil Plants.	*Chairman.*—Professor F.W. Oliver. *Secretary.*—Professor F. E Weiss. Mr. E. Newell Arber, Professor A.C. Seward, and Dr. D. H. Scott.	15 0 0
The Investigation of the Jurassic Flora of Yorkshire.	*Chairman.*—Professor A. C. Seward. *Secretary.*—Mr. H. Hamshaw Thomas. Mr. H. W T. Wager and Professor F. E. Weiss.	5 0 0
The Investigations of the Flora of the Peat of the Kennet Valley, Berks.	*Chairman.*—Professor F. Keeble. *Secretary.*—Miss M. C. Rayner. Professors F. W. Oliver and F. E. Weiss.	15 0 0
The Investigation of the Vegetation of Ditcham Park, Hampshire.	*Chairman.*—Mr A. G. Tansley. *Secretary.*—Mr. R. S. Adamson. Dr. C. E. Moss and Professor R. H. Yapp.	20 0 0
Experimental Studies in the Physiology of Heredity.	*Chairman.*—Professor F. F. Blackman. *Secretary.*—Mr. R. P. Gregory. Professors Bateson and Keeble.	30 0 0
The Renting of Cinchona Botanic Station in Jamaica.	*Chairman.*—Professor F. O. Bower. *Secretary.*—Professor R. H Yapp. Professors R. Buller, F. W. Oliver, and F. E. Weiss.	25 0 0
To carry out Breeding Experiments with Œnotheras.	*Chairman.*— Professor W. Bateson. *Secretary.*—Professor F. Keeble. Mr. R. P. Gregory.	20 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants
SECTION L.—EDUCATIONAL SCIENCE.		£ s. d.
To inquire into and report upon the methods and results of research into the Mental and Physical Factors involved in Education.	*Chairman.*— *Secretary.*—Professor J. A. Green. Professor J. Adams, Dr. G. A. Auden, Sir E. Brabrook, Dr. W. Brown, Mr. C Burt, Professor E. P. Culverwell, Mr. G. F. Daniell, Miss B. Foxley, Professor R. A. Gregory, Dr. C. W. Kimmins, Professor W. McDougall, Dr. C. S. Myers, Dr. T. P. Nunn, Dr. W. H. R. Rivers, Dr. F. C. Shrubsall, Mr. H. Bompas Smith, Dr. C. Spearman, and Mr. A. E. Twentyman.	30 0 0
The Influence of School Books upon Eyesight.	*Chairman.*—Dr. G. A. Auden. *Secretary.*—Mr. G. F. Daniell. Mr. C. H. Bothamley, Mr. W. D. Eggar, Professor R. A. Gregory, Mr. J. L. Holland, Dr. W. E. Sumpner, and Mr. Trevor Walsh.	15 15 3
To inquire into and report on the number, distribution and respective Values of Scholarships, Exhibitions and Bursaries held by University Students during their undergraduate course, and on funds private and open available for their augmentation.	*Chairman.*—Sir Henry Miers. *Secretary.*—Professor Marcus Hartog. Miss Lilian J. Clarke, Miss B. Foxley, Professor H. Bompas Smith, and Principal Griffiths.	5 0 0
To examine, inquire into and report on the Character, Work and Maintenance of Museums, with a view to their Organisation and Development as Institutions for Education and Research; and especially to inquire into the Requirements of Schools.	*Chairman.*—Professor J. A. Green. *Secretaries.*—Mr. H. Bolton and Dr J. A. Clubb. Dr. Bather, Mr. E Gray, Professor S. F. Harmer, Mr. M. D. Hill, Dr. W. E. Hoyle, Professors E. J. Garwood and P. Newberry, Sir Richard Temple, Mr. H. H. Thomas, Professor F. E. Weiss, Mrs. Dr. White, Rev. H. Browne, Drs. A. C. Haddon and H. S. Harrison, Mr. Herbert R. Rathbone, and Dr. W. M. Tattersall.	10 0 0
CORRESPONDING SOCIETIES.		
Corresponding Societies Committee for the preparation of their Report.	*Chairman.*—Mr. W. Whitaker. *Secretary.*—Mr. W. P. D. Stebbing. Rev. J. O. Bevan, Sir Edward Brabrook, Sir H. G. Fordham, Dr. J. G. Garson, Principal E. H. Griffiths, Dr. A. C. Haddon, Mr. T. V. Holmes, Mr. J. Hopkinson, Mr. A. L. Lewis, Rev. T. R. R. Stebbing, Mr. W. Mark Webb, and the President and General Officers of the Association.	25 0 0

2. *Not receiving Grants of Money.**

Subject for Investigation, or Purpose	Members of Committee
Section A.—MATHEMATICS AND PHYSICS.	
*Radiotelegraphic Investigations.	*Chairman.*—Sir Oliver Lodge. *Secretary.*—Dr. W. H. Eccles. Mr. S. G. Brown, Dr. C. Chree, Professor A. S. Eddington, Dr. Erskine-Murray, Professors J. A. Fleming, G. W. O Howe, and H. M. Macdonald, Sir H. Norman, Captain H. R. Sankey, Dr. A. Schuster, Dr. W. N. Shaw, and Professor S. P. Tnompson.
To aid the work of Establishing a Solar Observatory in Australia.	*Chairman.*— *Secretary.*—Dr. W. G. Duffield. Rev. A L. Cortie, Dr. W. J S. Lockyer, Mr. F. McClean, and Professors A. Schuster and H. H. Turner.
To consider the Nomenclature and Definitions of Magnetic and Electrical Quantities.	*Chairman.*—Professor Silvanus Thompson. *Secretary.*—Professor F. G. Baily. Professors H. L. Callendar, J. A. Fleming, A. W. Porter, and A. Schuster, and Mr. F. E. Smith.
Section C.—GEOLOGY.	
The Collection, Preservation, and Systematic Registration of Photographs of Geological Interest.	*Chairman.*—Professor J. Geikie. *Secretaries.*—Professors W. W. Watts and S. H. Reynolds. Mr. G. Bingley, Dr. T. G. Bonney, Mr. C. V. Crook, Professor E. J. Garwood, and Messrs. R. Kidston, A. S. Reid, J. J. H. Teall, R. Welch, W. Whitaker, and H. B. Woodward.
To investigate the Microscopical and Chemical Composition of Charnwood Rocks.	*Chairman.*—Professor W. W. Watts. *Secretary.*—Dr. T. T. Groom. Dr. F. W. Bennett and Dr. Stracey.
The further Exploration of the Upper Red Sandstone of Dura Den.	*Chairman.*—Dr. J. Horne *Secretary.*—Dr. T. J. Jehu. Messrs. H. Bolton and A. W. R. Don, Dr. J. S. Flett, Dr. B. N. Peach, and Dr. A. Smith Woodward.
To consider the Preparation of a List of Stratigraphical Names, used in the British Isles, in connection with the Lexicon of Stratigraphical Names in course of preparation by the International Geological Congress.	*Chairman.*—Dr. J. E Marr. *Secretary*—Dr. F. A. Bather. Professor Grenville Cole, Mr. Bernard Hobson, Professor Lebour, Dr. J. Horne, Dr. A. Strahan, and Professor W. W. Watts.

* Excepting the case of Committees receiving grants from the Caird Fund, for which see p. lxvi.

2. *Not receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee
Section D.—ZOOLOGY.	
*To aid competent Investigators selected by the Committee to carry on definite pieces of work at the Zoological Station at Naples.	*Chairman.*—Mr. E. S. Goodrich. *Secretary.*—Dr. J. H. Ashworth. Mr. G. P. Bidder, Drs. W. B. Hardy and S. F. Harmer, Professor S. J. Hickson, Sir E. Ray Lankester, Professor W. C. McIntosh, and Dr. A. D. Waller.
To investigate the Feeding Habits of British Birds by a study of the contents of the crops and gizzards of both adults and nestlings, and by collation of observational evidence, with the object of obtaining precise knowledge as to the economic status of many of our commoner birds affecting rural science.	*Chairman.*—Dr. A. E. Shipley. *Secretary.*—Mr. H. S. Leigh. Messrs. J. N. Halbert, Robert Newstead, Clement Reid, A. G. L. Rogers, and F. V. Theobald, Professor F. E. Weiss, Dr. C. Gordon Hewitt, and Professors S. J. Hickson, F. W. Gamble, G. H. Carpenter, and J. Arthur Thomson.
To defray expenses connected with work on the Inheritance and Development of Secondary Sexual Characters in Birds.	*Chairman.*—Professor G. C. Bourne. *Secretary.*—Mr. Geoffrey Smith. Mr. E. S. Goodrich, Dr. W. T. Calman, and Dr. Marett Tims.
To summon meetings in London or elsewhere for the consideration of matters affecting the interests of Zoology or Zoologists, and to obtain by correspondence the opinion of Zoologists on matters of a similar kind, with power to raise by subscription from each Zoologist a sum of money for defraying current expenses of the Organisation.	*Chairman.*—Sir E. Ray Lankester. *Secretary.*—Professor S. J. Hickson. Professors G. C. Bourne, J. Cossar Ewart, M. Hartog, and W. A. Herdman, Mr. M. D. Hill, Professors J. Graham Kerr and Minchin, Dr. P. Chalmers Mitchell, Professors E. B. Poulton and Stanley Gardiner, and Dr. A. E. Shipley.
To nominate competent Naturalists to perform definite pieces of work at the Marine Laboratory, Plymouth.	*Chairman* and *Secretary.*—Professor A. Dendy. Sir E. Ray Lankester, Professor J. P. Hill, Professor Sydney H. Vines, and Mr. E. S. Goodrich.
To enable Mr. Laurie to conduct Experiments in Inheritance.	*Chairman.*—Professor W. A. Herdman. *Secretary.*—Mr. Douglas Laurie. Professor R. C. Punnett and Dr. H. W. Marett Tims.
To formulate a Definite System on which Collectors should record their captures.	*Chairman.*—Professor J. W. H. Trail. *Secretary.*—Mr. F. Balfour Browne. Drs. Scharff and E. J. Bles, Professors G. H. Carpenter and E. B. Poulton, and Messrs. A. G. Tansley and R. Lloyd Praeger.
A Natural History Survey of the Isle of Man.	*Chairman.*—Professor W. A. Herdman. *Secretary.*—Mr. P. M. C. Kermode. Dr. W. T. Calman, Rev. J. Davidson, Mr. G. W. Lamplugh, Professor E. W. MacBride, and Lord Raglan.

2. *Not receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee
Section F.—ECONOMIC SCIENCE AND STATISTICS.	
The question of Fatigue from the Economic Standpoint, if possible in co-operation with Section I, Sub-section of Psychology.	*Chairman.*—Professor Muirhead. *Secretary.*—Miss Hutchins. Miss A. M. Anderson, Professor W. J. Ashley, Professor F. A. Bainbridge, Mr. E. Cadbury, Mr. P. Sargant Florence, Professor Stanley Kent, Mr. W. J. Layton, Dr. T. G. Maitland, Miss M. C. Matheson, Dr. C. S. Myers, Mr. J. W. Ramsbottom, and Dr. Jenkins Robb.
Section H.—ANTHROPOLOGY.	
The Collection, Preservation and Systematic Registration of Photographs of Anthropological Interest.	*Chairman.*—Sir C. H Read. *Secretary.*—Mr. E. W. Martindell. Dr. G. A. Auden, Mr. E. Heawood, and Professor J. L. Myres.
To conduct Archæological and Ethnological Researches in Crete.	*Chairman.*—Mr. D. G. Hogarth. *Secretary.*—Professor J. L. Myres. Professor R. C. Bosanquet, Dr. W. L. H. Duckworth, Sir A. J. Evans, Professor W. Ridgeway, and Dr. F. C. Shrubsall.
To produce certified copies of the Hausa Manuscripts in the possession of Major Tremearne, for deposit in centres at which Hausa is taught and students prepared for the Government Service.	*Chairman.*—Mr. E. Sidney Hartland. *Secretary* —Professor J. L. Myres. Mr. W. Crooke and Major A. J. N. Tremearne.
To report on the present state of knowledge of the Prehistoric Civilisation of the Western Mediterranean with a view to future research.	*Chairman.*—Professor W. Ridgeway. *Secretary.*—Dr. T. Ashby. Dr. W. L. H. Duckworth, Mr. D. G. Hogarth, Sir A. J. Evans, and Professor J. L. Myres.
To co-operate with a Local Committee in the Excavation of a Prehistoric Site at Bishop's Stortford.	*Chairman.*—Professor W. Ridgeway. *Secretary.*—Dr. W. L. H. Duckworth. Professor W. Boyd Dawkins, Dr. A. C. Haddon, Rev. Dr. A. Irving, and Dr. H. W. Marett Tims.
To conduct Excavations in Easter Island.	*Chairman.*—Dr. A. C. Haddon. *Secretary.*—Dr. W. H. R. Rivers. Mr. R. R. Marett and Dr. C. G. Seligmann.
To report on Palæolithic Sites in the West of England.	*Chairman.*—Professor Boyd Dawkins. *Secretary.*—Dr. W. L. H. Duckworth. Professor A. Keith.

2. *Not receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee
The Teaching of Anthropology.	*Chairman.*—Sir Richard Temple. *Secretary.*—Dr. A. C. Haddon. Sir E. F. im Thurn, Mr. W. Crooke, Dr. C. G. Seligmann, Professor G. Elliot Smith, Dr. R. R. Marett, Professor P. E. Newberry, Dr. G. A. Auden, Professors T. H. Bryce, P. Thompson, R. W. Reid, H. J. Fleure, and J. L. Myres, and Sir B. C. A. Windle.
To excavate Early Sites in Macedonia.	*Chairman.*—Professor W. Ridgeway. *Secretary.*—Mr. A. J. B. Wace. Professors R. C. Bosanquet and J. L. Myres.
To report on the Distribution of Bronze Age Implements.	*Chairman.*—Professor J. L. Myres. *Secretary.*—Mr. H. Peake. Sir Arthur Evans, Professor W. Ridgeway, Mr. H. Balfour, Sir C. H. Read, and Professor W. Boyd Dawkins.

SECTION I.—PHYSIOLOGY.

Effect of Low Temperature on Cold-blooded Animals.	*Chairman.*—Professor Swale Vincent. *Secretary.*—Mr. A. T. Cameron.
Electromotive Phenomena in Plants.	*Chairman.*—Dr. A. D. Waller. *Secretary.*—Mrs. Waller. Professors J. B. Farmer and Veley and Dr. F. O'B. Ellison.
The Dissociation of Oxy-Hæmoglobin at High Altitudes.	*Chairman.*—Professor E. H. Starling. *Secretary.*—Dr. J. Barcroft. Dr. W. B. Hardy.
Colour Vision and Colour Blindness.	*Chairman.*—Professor E. H. Starling. *Secretary.*—Dr. Edridge-Green. Professor Leonard Hill, Professor A. W. Porter, Dr. A. D. Waller, Professor C. S. Sherrington, and Dr. F. W. Mott.
To investigate the Physiological and Psychological Factors in the production of Miners' Nystagmus.	*Chairman.*—Professor J. H. Muirhead. *Secretary.*—Dr. T. G. Maitland. Dr. J. Jameson Evans and Dr. C. S. Myers.

SECTION K.—BOTANY.

To consider and report on the advisability and the best means of securing definite Areas for the Preservation of Types of British Vegetation.	*Chairman.*—Professor F. E. Weiss. *Secretary.*—Mr. A. G. Tansley. Professor J. W. H. Trail, Mr. R. Lloyd Praeger, Professor F. W. Oliver, Professor R. W. Phillips, Dr. C. E. Moss, and Messrs. G. C. Druce and H. W. T. Wager.

2. *Not receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee
Section L.—EDUCATIONAL SCIENCE.	
To take notice of, and report upon changes in, Regulations—whether Legislative, Administrative, or made by Local Authorities — affecting Secondary and Higher Education.	*Chairman.*—Professor H. E. Armstrong. *Secretary.*—Major E. Gray. Miss Coignan, Principal Griffiths, Dr. C. W. Kimmins, Sir Horace Plunkett, Mr. H. Ramage, Professor M. E. Sadler, and Rt. Rev. J. E. C. Welldon.
The Aims and Limits of Examinations.	*Chairman.*—Professor M. E. Sadler. *Secretary.*—Mr. P. J. Hartog. Mr. D. P. Berridge, Professor G. H. Bryan, Mr. W. D. Eggar, Professor R. A. Gregory, Principal E. H. Griffiths, Miss C. L. Laurie, Dr. W. McDougall, Mr. David Mair, Dr. T. P. Nunn, Sir W. Ramsay, Rt. Rev. J. E. C. Welldon, Dr. Jessie White, and Mr. G. U. Yule.

Communications ordered to be printed in extenso.

Section A.—As many of the remarks made in the Discussion on Radiation as the Recorder may be able to obtain.

Section B.—The Papers comprising the Discussion on the Proper Utilisation of Coal and Fuels derived therefrom.

Section C.—Professor W. J. Sollas: The Formation of 'Rostro-carinate' Flints.

Section D.—Professor J. Versluys: The Carapace of the Chelonia.

Section G.—Professor F. W. Burstall: Liquid, Solid, and Gaseous Fuels for Power Production.

Resolutions referred to the Council for consideration, and, if desirable, for action.

(*a*) Resolutions relating to the Caird Fund (see p. xlii).

(1) That the Council be asked to appoint a Committee to carry out the request of Sir J. K. Caird in his letter of September 10 (viz., that his further gift of 1,000*l.* be earmarked for the study of Radio-activity as a branch of Geophysics.

(2) That the request of Section A (Mathematics and Physics) for a grant from the Caird Fund of 500*l.* for Radiotelegraphic Investigations be sent to the Council for consideration and action.

(3) That a grant of 100*l.* for the coming year be made to the Committee on the Naples Table from the Caird Fund, and that the Council be requested to consider the advisability of endowing the Committee with a capital sum yielding an annual income of 100*l.*

(4) That a grant of 100*l.* for the coming year be made to the Committee on Seismological Investigations from the Caird Fund, and that the Council be asked to consider the advisability of endowing the Committee with a capital sum yielding an annual income of 100*l.*

(*b*) Other Resolutions.

From Sections A and E.

That the terms First Order, Second Order, Third Order, and Fourth Order of Triangulation, as connoting different degrees of precision, be used to describe

triangulation, even though the terms now in use (*e.g.*, Major, Minor, etc.), which have only a local significance, are also employed.

That this resolution be communicated through the proper channels to (*a*) the Geodetic Association, and (*b*) the Institute of Surveyors.

From Section I.

That in view of the fact that numerous deaths continue to take place from anæsthetics administered by unregistered persons, the Committee of the Section of Physiology of the British Association appeals to the Council of the Association to represent to the Home Office and to the Privy Council the urgent need of legislation to protect the public against such unnecessary risks.

From Section I.

The Committee of Section I requests the Council of the Association to forward to the Board of Trade the following resolution:—

(i) That colour vision tests are most efficiently conducted by means of what is known as the 'Lantern Test.'

(ii) That the best form of such lantern has not yet been finally decided upon, and can be arrived at only after further expert report.

(iii) That the actual application of sight tests requires the co-operation of an ophthalmic surgeon with a practical navigator.

*

Synopsis of Grants of Money (exclusive of Grants from the Caird Fund) appropriated for Scientific Purposes by the General Committee at the Birmingham Meeting, September 1913. *The Names of Members entitled to call on the General Treasurer for the Grants are prefixed to the respective Research Committees.*

Section A.—Mathematical and Physical Science.

	£	s.	d.
*Turner, Professor H. H.—Seismological Observations	60	0	0
In addition, the Council are authorised to expend on the printing of circulars, &c., in connection with the Committee on Seismological Observations a sum not exceeding	70	0	0
*Shaw, Dr. W. N.—Upper Atmosphere	25	0	0
*Ramsay, Sir W.—Grant to the International Commission on Physical and Chemical Constants	40	0	0
*Hill, Professor M. J. M.—Calculation of Mathematical Tables	20	0	0
Cunningham, Lieut.-Col. A.—Copies of the 'Binary Canon,' for presentation	5	0	0

Section B.—Chemistry.

*Perkin, Dr. W. H.—Study of Hydro-aromatic Substances	15	0	0
*Armstrong, Professor H. E.—Dynamic Isomerism	25	0	0
*Kipping, Professor F. S.—Transformation of Aromatic Nitroamines	15	0	0
*Hall, A. D.—Study of Plant Enzymes	25	0	0
Pope, Professor W. J.—Correlation of Crystalline Form with Molecular Structure	25	0	0
Armstrong, Professor H. E.—Solubility Phenomena	15	0	0

Section C.—Geology.

*Tiddeman, R. H.—Erratic Blocks	5	0	0
*Kendall, Professor P. F.—List of Characteristic Fossils	5	0	0
Strahan, Dr. A. Geology of Ramsay Island, Pembroke ...	10	0	0
Cole, Professor Grenville.—Old Red Sandstone Rocks of Kiltorcan	10	0	0
Barrow, G.—Trias of Western Midlands	10	0	0
Watts, Professor W. W.—Sections in Lower Palæozoic Rocks	15	0	0

Section D.—Zoology.

*Shipley, Dr. A. E.—Belmullet Whaling Station	20	0	0
Mitchell, Dr. Chalmers.—Nomenclator Animalium	50	0	0
Harmer, Dr. S. F.—Antarctic Whaling Industry	90	0	0
Carried forward	£555	0	0

* Reappointed

	£	s.	d.
Brought forward	555	0	0

Section E.—Geography.

	£	s.	d.
*Myres, Professor J. L.—Maps for School and University Use	40	0	0
Dickson, Professor H. N.—Tidal Currents in Moray and adjacent Firths	40	0	0

Section G.—Engineering.

	£	s.	d.
*Preece, Sir W. H.—Gaseous Explosions	50	0	0
*Perry, Professor J.—Stress Distributions	50	0	0

Section H.—Anthropology.

	£	s.	d.
Dawkins, Professor Boyd.—Lake Villages in the neighbourhood of Glastonbury	20	0	0
*Read, Sir C. H.—Age of Stone Circles	20	0	0
Dawkins, Professor Boyd.—Artificial Islands in Highland Lochs	5	0	0
*Smith, Professor G. Elliot.—Physical Characters of the Ancient Egyptians	34	16	6
*Ridgeway, Professor W.—Roman Sites in Britain	20	0	0
Myres, Professor J. L.—Anthropometric Investigations in Cyprus	50	0	0
Marett, Dr. R. R.—Palæolithic Site in Jersey	50	0	0

Section I.—Physiology.

	£	s.	d.
*Schafer, Sir E. A.—The Ductless Glands	35	0	0
*Waller, Dr. A. D.—Anæsthetics	20	0	0
*Macdonald, Professor J. S.—Calorimetric Observations	40	0	0
Sherrington, Professor C. S.—Mammalian Heart	30	0	0
Myers, Dr. C. S.—Binocular Combination of Kinematograph Pictures	10	0	0

Section K.—Botany.

	£	s.	d.
*Oliver, Professor F. W.—Structure of Fossil Plants	15	0	0
*Seward, Professor A. C.—Jurassic Flora of Yorkshire	5	0	0
Keeble, Professor F.—Flora of Peat of Kennet Valley	15	0	0
Tansley, A. G.—Vegetation of Ditcham Park	20	0	0
Blackman, Professor F. F.—Physiology of Heredity	30	0	0
Bower, Professor F. O.—Renting of Cinchona Botanic Station, Jamaica	25	0	0
Bateson, Professor W.—Breeding Experiments in Œnotheras	20	0	0
Carried forward	£1,199	16	6

* Reappointed.

	£	s.	d.
Brought forward	1,199	16	6

Section L.—Education.

	£	s.	d.
—Mental and Physical Factors involved in Education	30	0	0
*Auden, Dr. G. A.—Influence of School Books on Eyesight...	15	15	3
*Miers, Sir H.—Scholarships, &c., held by University Students	5	0	0
Green, Professor J. A.—Character, Work, and Maintenance of Museums	10	0	0

Corresponding Societies Committee.

	£	s.	d.
*Whitaker, W.—For Preparation of Report	25	0	0
Total	£1,285	11	9

* Reappointed.

CAIRD FUND.

An unconditional gift of 10,000*l.* was made to the Association at the Dundee Meeting, 1912, by Mr. (afterwards Sir) J. K. Caird, LL.D., of Dundee.

The Council in its Report to the General Committee at the Birmingham Meeting made certain recommendations as to the administration of this Fund (§ VII., p. xlii). These recommendations were adopted, with the Report, by the General Committee at its meeting on September 10, 1913.

Recommendations were made by certain Sectional Committees at Birmingham of grants from the Caird Fund, for which see p. lxii.

The following allocations have been made from the Fund by the Council (including those made at the Council meeting on November 7, 1913, the first ordinary meeting following the Birmingham Meeting):—

Naples Zoological Station Committee (p. lix).—50*l.* (1912-13); 100*l.* (1913-14); 100*l.* annually in future, subject to the adoption of the Committee's report.

Seismology Committee (p. li).—100*l.* (1913-14); 100*l.* annually in future, subject to the adoption of the Committee's report.

Radiotelegraphic Committee (p. lviii). 500*l.* (1913 14).

Magnetic Re-survey of the British Isles (in collaboration with the Royal Society).—250*l.*

Sir J. K. Caird, on September 10, 1913, made a further gift of 1,000*l.* to the Association, to be devoted to the study of Radio-activity.

Annual Meetings, 1914 *and* 1915.

The Annual Meeting of the Association in 1914 will be held in Australia in August; in 1915, at Manchester.

PRESIDENT'S ADDRESS.

ADDRESS

BY

Sir OLIVER J. LODGE, D.Sc., LL.D., F.R.S.,

PRESIDENT.

CONTINUITY.

First let me lament the catastrophe which has led to my occupying the Chair here in this City. Sir William White was a personal friend of many here present, and I would that the citizens of Birmingham could have become acquainted with his attractive personality, and heard at first hand of the strenuous work which he accomplished in carrying out the behests of the Empire in the construction of its first line of defence.

Although a British Association Address is hardly an annual stock-taking, it would be improper to begin this year of Office without referring to three more of our losses:—One, that cultured gentleman, amateur of science in the best sense, who was chosen to preside over our Jubilee meeting at York thirty-two years ago. Sir John Lubbock, first Baron Avebury, cultivated science in a spirit of pure enjoyment, treating it almost as one of the Arts; and he devoted social and political energy to the welfare of the multitude of his fellows less fortunately situated than himself.

Through the untimely death of Sir George Darwin the world has lost a mathematical astronomer whose work on the Tides and allied phenomena is a monument of power and achievement. So recently as our visit to South Africa he occupied the Presidential Chair.

By the third of our major losses, I mean the death of that brilliant Mathematician of a neighbouring nation who took so comprehensive and philosophic a grasp of the intricacies of physics, and whose eloquent though sceptical exposition of our laws and processes, and of the modifications entailed in them by recent advances, will be sure to attract still more widespread attention among all to whom the rather abstruse subject-matter is sufficiently familiar. I cannot say that I find myself in agreement with all that Henri Poincaré wrote or spoke

in the domain of physics, but no physicist can help being interested in his mode of presentation, and I may have occasion to refer, in passing, to some of the topics with which he dealt.

And now, eliminating from our purview, as is always necessary, a great mass of human activity, and limiting ourselves to a scrutiny on the side of pure science alone, let us ask what, in the main, is the characteristic of the promising though perturbing period in which we live. Different persons would give different answers, but the answer I venture to give is—Rapid progress, combined with Fundamental scepticism.

Rapid progress was not characteristic of the latter half of the nineteenth century,—at least not in physics. Fine solid dynamical foundations were laid, and the edifice of knowledge was consolidated; but wholly fresh ground was not being opened up, and totally new buildings were not expected.

> 'In many cases the student was led to believe that the main facts of nature were all known, that the chances of any great discovery being made by experiment were vanishingly small, and that therefore the experimentalist's work consisted in deciding between rival theories, or in finding some small residual effect, which might add a more or less important detail to the theory.'—*Schuster.*

With the realisation of predicted ether waves in 1888, the discovery of X-rays in 1895, spontaneous radioactivity in 1896, and the isolation of the electron in 1898, expectation of further achievement became vivid; and novelties, experimental, theoretical, and speculative, have been showered upon us ever since this century began. That is why I speak of rapid progress.

Of the progress I shall say little,—there must always be some uncertainty as to which particular achievement permanently contributes to it; but I will speak about the fundamental scepticism.

Let me hasten to explain that I do not mean the well-worn and almost antique theme of Theological scepticism: that controversy is practically in abeyance just now. At any rate the major conflict is suspended; the forts behind which the enemy has retreated do not invite attack; the territory now occupied by him is little more than his legitimate province. It is the scientific allies, now, who are waging a more or less invigorating conflict among themselves; with Philosophers joining in. Meanwhile the ancient foe is biding his time and hoping that from the struggle something will emerge of benefit to himself. Some positions, he feels, were too hastily abandoned and may perhaps be retrieved; or, to put it without metaphor, it seems possible that a few of the things prematurely denied, because asserted

on inconclusive evidence, may after all, in some form or other, have really happened. Thus the old theological bitterness is mitigated, and a temporising policy is either advocated or instinctively adopted.

To illustrate the nature of the fundamental scientific or philosophic controversies to which I do refer, would require almost as many addresses as there are Sections of the British Association, or at any rate as many as there are chief cities in Australia; and perhaps my successor in the Chair will continue the theme; but, to exhibit my meaning very briefly, I may cite the kind of dominating controversies now extant, employing as far as possible only a single word in each case so as to emphasise the necessary brevity and insufficiency of the reference.

In Physiology the conflict ranges round *Vitalism*. (My immediate predecessor dealt with the subject at Dundee.)

In Chemistry the debate concerns *Atomic structure*. (My penultimate predecessor is well aware of pugnacity in that region.)

In Biology the dispute is on the laws of *Inheritance*. (My nominated successor is likely to deal with this subject; probably in a way not deficient in liveliness.)

And besides these major controversies, debate is active in other sections:—

In Education, *Curricula* generally are being overhauled or fundamentally criticised, and revolutionary ideas are promulgated concerning the advantages of freedom for infants.

In Economic and Political Science, or Sociology, what is there that is not under discussion? Not property alone, nor land alone, but everything,—back to the Garden of Eden and the interrelations of men and women.

Lastly, in the vast group of Mathematical and Physical Sciences, 'slurred over rather than summed up as Section A,' present-day scepticism concerns what, if I had to express it in one word, I should call *Continuity*. The full meaning of this term will hardly be intelligible without explanation, and I shall discuss it presently.

Still more fundamental and deep-rooted than any of these sectional debates, however, a critical examination of scientific foundations generally is going on; and a kind of philosophic scepticism is in the ascendant, resulting in a mistrust of purely intellectual processes and in a recognition of the limited scope of science.

For science is undoubtedly an affair of the intellect, it examines everything in the cold light of reason; and that is its strength. It is a commonplace to say that science must have no likes or dislikes, must aim only at truth; or as Bertrand Russell well puts it:—

'The kernel of the scientific outlook is the refusal to regard

> our own desires, tastes, and interests as affording a key to the understanding of the world.'

This exclusive single-eyed attitude of science is its strength; but, if pressed beyond the positive region of usefulness into a field of dogmatic negation and philosophising, it becomes also its weakness. For the nature of man is a large thing, and intellect is only a part of it: a recent part too, which therefore necessarily, though not consciously, suffers from some of the defects of newness and crudity, and should refrain from imagining itself the whole—perhaps it is not even the best part—of human nature.

The fact is that some of the best things are, by abstraction, excluded from Science, though not from Literature and Poetry; hence perhaps an ancient mistrust or dislike of science, typified by the Promethean legend. Science is systematised and *metrical* knowledge, and in regions where measurement cannot be applied it has small scope; or, as Mr. Balfour said the other day at the opening of a new wing of the National Physical Laboratory,

> 'Science depends on measurement, and things not measurable are therefore excluded, or tend to be excluded, from its attention. But Life and Beauty and Happiness are not measurable.' And then characteristically he added:—'If there could be a unit of happiness, Politics might begin to be scientific.'

Emotion and Intuition and Instinct are immensely older than science, and in a comprehensive survey of existence they cannot be ignored. Scientific men may rightly neglect them, in order to do their proper work, but philosophers cannot.

So Philosophers have begun to question some of the larger generalisations of science, and to ask whether in the effort to be universal and comprehensive we have not extended our laboratory inductions too far. The Conservation of Energy, for instance,—is it always and everywhere valid; or may it under some conditions be disobeyed? It would seem as if the second law of Thermodynamics must be somewhere disobeyed—at least if the age of the Universe is both ways infinite,—else the final consummation would have already arrived.

Not by philosophers only, but by scientific men also, ancient postulates are being pulled up by the roots. Physicists and Mathematicians are beginning to consider whether the long-known and well-established laws of mechanics hold true everywhere and always, or whether the Newtonian scheme must be replaced by something more modern, something to which Newton's laws of motion are but an approximation.

Indeed a whole system of non-Newtonian Mechanics has been devised, having as its foundation the recently discovered changes which

must occur in bodies moving at speeds nearly comparable with that of light. It turns out in fact that both Shape and Mass are functions of Velocity. As the speed increases the mass increases and the shape is distorted, though under ordinary conditions only to an infinitesimal extent.

So far I agree; I agree with the statement of fact; but I do not consider it so revolutionary as to overturn Newtonian mechanics. After all, a variation of Mass is familiar enough, and it would be a great mistake to say that Newton's second law breaks down merely because Mass is not constant. A raindrop is an example of variable mass; or the earth may be, by reason of meteoric dust; or the sun, by reason of radio-activity; or a locomotive, by reason of the emission of steam. In fact, variable masses are the commonest, for friction may abrade any moving body to a microscopic extent.

That Mass is constant is only an approximation. That Mass is equal to ratio of Force and Acceleration is a definition, and can be absolutely accurate. It holds perfectly even for an electron with a speed near that of light; and it is by means of Newton's second law that the variation of Mass with Velocity has been experimentally observed and compared with theory.

I urge that we remain with, or go back to, Newton. I see no reason against retaining all Newton's laws, discarding nothing, but supplementing them in the light of further knowledge.

Even the laws of Geometry have been overhauled, and Euclidean Geometry is seen to be but a special case of more fundamental generalisations. How far they apply to existing space, and how far Time is a reality or an illusion, and whether it can in any sense depend on the motion or the position of an observer: all these things in some form or other are discussed.

The Conservation of Matter also, that main-mast of nineteenth century chemistry, and the existence of the Ether of Space, that sheet-anchor of nineteenth century physics,—do they not sometimes seem to be going by the board?

Professor Schuster, in his American lectures, commented on the modern receptive attitude as follows:—

> 'The state of plasticity and flux—a healthy state, in my opinion,—in which scientific thought of the present day adapts itself to almost any novelty, is illustrated by the complacency with which the most cherished tenets of our fathers are being abandoned. Though it was never an article of orthodox faith that chemical elements were immutable and would not some day be resolved into simpler constituents, yet the conservation of mass seemed to lie at the very foundation of creation. But now-a-days

> the student finds little to disturb him, perhaps too little, in the idea that mass changes with velocity; and he does not always realise the full meaning of the consequences which are involved.'

This readiness to accept and incorporate new facts into the scheme of physics may have led to perhaps an undue amount of scientific scepticism, in order to right the balance.

But a still deeper variety of comprehensive scepticism exists, and it is argued that all our laws of nature, so laboriously ascertained and carefully formulated, are but conventions after all, not truths: that we have no faculty for ascertaining real truth, that our intelligence was not evolved for any such academic purpose; that all we can do is to express things in a form convenient for present purposes and employ that mode of expression as a tentative and pragmatically useful explanation.

Even *explanation*, however, has been discarded as too ambitious by some men of science, who claim only the power to describe. They not only emphasise the *how* rather than the *why*,—as is in some sort inevitable, since explanations are never ultimate—but are satisfied with very abstract propositions, and regard mathematical equations as preferable to, because safer than, mechanical analogies or models.

> 'To use an acute and familiar expression of Gustav Kirchhoff, it is the object of science to *describe* natural phenomena, not to *explain* them. When we have expressed by an equation the correct relationship between different natural phenomena we have gone as far as we safely can, and if we go beyond we are entering on purely speculative ground.'

But the modes of statement preferred by those who distrust our power of going correctly into detail are far from satisfactory. Professor Schuster describes and comments on them thus:—

> 'Vagueness, which used to be recognised as our great enemy, is now being enshrined as an idol to be worshipped. We may never know what constitutes atoms, or what is the real structure of the ether; why trouble, therefore, it is said, to find out more about them. Is it not safer, on the contrary, to confine ourselves to a general talk on entropy, luminiferous vectors, and undefined symbols expressing vaguely certain physical relationships? What really lies at the bottom of the great fascination which these new doctrines exert on the present generation is sheer cowardice; the fear of having its errors brought home to it.' . . .

'I believe this doctrine to be fatal to a healthy development of science. Granting the impossibility of penetrating beyond the

most superficial layers of observed phenomena, I would put the distinction between the two attitudes of mind in this way: One glorifies our ignorance, while the other accepts it as a regrettable necessity.'

With this criticism I am in accord.

In further illustration of the modern sceptical attitude, I quote from Poincaré:—

'Principles are conventions and definitions in disguise. They are, however, deduced from experimental laws, and these laws have, so to speak, been erected into principles to which our mind attributes an absolute value.' . . .

'The fundamental propositions of geometry, for instance Euclid's postulate, are only conventions; and it is quite as unreasonable to ask if they are true or false as to ask if the metric system is true or false. Only, these conventions are convenient.' . . .

'Whether the ether exists or not matters little,—let us leave that to the metaphysicians; what is essential for us is that everything happens as if it existed, and that this hypothesis is found to be suitable for the explanation of phenomena. After all, have we any other reason for believing in the existence of material objects? That, too, is only a convenient hypothesis.'

A needed antidote against over-pressing these utterances, however, is provided by Sir J. Larmor in his Preface:—

'There has been of late a growing trend of opinion, prompted in part by general philosophical views, in the direction that the theoretical constructions of physical science are largely factitious, that instead of presenting a valid image of the relations of things on which further progress can be based, they are still little better than a mirage.' . . .

'The best method of abating this scepticism is to become acquainted with the real scope and modes of application of conceptions which, in the popular language of superficial exposition—and even in the unguarded and playful paradox of their authors, intended only for the instructed eye—often look bizarre enough.'

One thing is very notable, that it is closer and more exact knowledge that has led to the kind of scientific scepticism now referred to; and that the simple laws on which we used to be working were thus simple and discoverable because the full complexity of existence was tempered to our ken by the roughness of our means of observation.

Kepler's laws are not accurately true, and if he had had before him all the data now available he could hardly have discovered them. A

planet does not really move in an ellipse but in a kind of hypocycloid, and not accurately in that either.

So it is also with Boyle's law, and the other simple laws in Physical Chemistry. Even Van der Waals' generalisation of Boyle's law is only a further approximation.

In most parts of physics simplicity has sooner or later to give place to complexity: though certainly I urge that the simple laws were true, and are still true, as far as they go, their inaccuracy being only detected by further real discovery. The reason they are departed from becomes known to us; the law is not really disobeyed, but is modified through the action of a known additional cause. Hence it is all in the direction of progress.

It is only fair to quote Poincaré again, now that I am able in the main to agree with him—

> 'Take for instance the laws of reflection. Fresnel established them by a simple and attractive theory which experiment seemed to confirm. Subsequently, more accurate researches have shown that this verification was but approximate; traces of elliptic polarisation were detected everywhere. But it is owing to the first approximation that the cause of these anomalies was found, in the existence of a transition layer; and all the essentials of Fresnel's theory have remained. We cannot help reflecting that all these relations would never have been noted if there had been doubt in the first place as to the complexity of the objects they connect. Long ago it was said: If Tycho had had instruments ten times as precise, we would never have had a Kepler, or a Newton, or Astronomy. It is a misfortune for a science to be born too late, when the means of observation have become too perfect. That is what is happening at this moment with respect to physical chemistry: the founders are hampered in their general grasp by third and fourth decimal places; happily they are men of robust faith. As we get to know the properties of matter better we see that continuity reigns. . . . . It would be difficult to justify [the belief in continuity] by apodeictic reasoning, but without [it] all science would be impossible.'

Here he touches on my own theme, *Continuity*; for, if we had to summarise the main trend of physical controversy at present, I feel inclined to urge that it largely turns on the question as to which way ultimate victory lies in the fight between Continuity and Discontinuity.

On the surface of nature at first we see discontinuity; objects detached and countable. Then we realise the air and other media, and so emphasise continuity and flowing quantities. Then we detect atoms

and numerical properties, and discontinuity once more makes its appearance. Then we invent the ether and are impressed with continuity again. But this is not likely to be the end; and what the ultimate end will be, or whether there is an ultimate end, is a question difficult to answer.

The modern tendency is to emphasise the discontinuous or atomic character of everything. Matter has long been atomic, in the same sense as Anthropology is atomic; the unit of matter is the atom, as the unit of humanity is the individual. Whether men or women or children—they can be counted as so many 'souls.' And atoms of matter can be counted too.

Certainly however there is an illusion of continuity. We recognise it in the cose of water. It appears to be a continuous medium, and yet it is certainly molecular. It is made continuous again, in a sense, by the ether postulated in its pores; for the ether is essentially continuous. Though Osborne Reynolds, it is true, invented a discontinuous or granular Ether, on the analogy of the sea shore. The sands of the sea, the hairs of the head, the descendants of a Patriarch, are typical instances of numerable, or rather of innumerable, things. The difficulty of enumerating them is not that there is nothing to count, but merely that the things to be courted are very numerous. So are the atoms in a drop of water,—they outnumber the drops in an Atlantic Ocean,—and, during the briefest time of stating their number, fifty millions or so may have evaporated; but they are as easy to count as the grains of sand on a shore.

The process of counting is evidently a process applicable to discontinuities, *i.e.*, to things with natural units; you can count apples and coins, and days and years, and people and atoms. To apply number to a continuum you must first cut it up into artificial units; and you are always left with incommensurable fractions. Thus only is it that you can deal numerically with such continuous phenomena as the warmth of a room, the speed of a bird, the pull of a rope, or the strength of a current.

But how, it may be asked, does discontinuity apply to number? The natural numbers, 1, 2, 3, etc., are discontinuous enough, but there are fractions to fill up the interstices; how do we know that they are not really connected by these fractions, and so made continuous again?

(By number I always mean commensurable number; incommensurables are not numbers: they are just what cannot be expressed in numbers. The square root of 2 is not a number, though it can be readily indicated by a length. Incommensurables are usual in physics and are frequent in geometry; the conceptions of geometry are essentially continuous. It is clear, as Poincaré says, that 'if the points

whose co-ordinates are commensurable were alone regarded as real, the in-circle of a square and the diagonal of the square would not intersect, since the co-ordinates of the points of intersection are incommensurable.')

I want to explain how commensurable fractions do not connect up numbers, nor remove their discontinuity in the least. The divisions on a foot rule, divided as closely as you please, represent commensurable fractions, but they represent none of the length. No matter how numerous they are, all the length lies between them; the divisions are mere partitions and have consumed none of it; nor do they connect up with each other, they are essentially discontinuous. The interspaces are infinitely more extensive than the barriers which partition them off from one another; they are like a row of compartments with infinitely thin walls. All the incommensurables lie in the interspaces; the compartments are full of them, and they are thus infinitely more numerous than the numerically expressible magnitudes. Take any point of the scale at random, that point will certainly lie in an interspace: it will not lie on a division, for the chances are infinity to 1 against it.

Accordingly incommensurable quantities are the rule in physics. Decimals do not in practice terminate or circulate, in other words vulgar fractions do not accidentally occur in any measurements, for this would mean infinite accuracy. We proceed to as many places of decimals as correspond to the order of accuracy aimed at.

Whenever, then, a commensurable number is really associated with any natural phenomenon, there is necessarily a noteworthy circumstance involved in the fact, and it means something quite definite and ultimately ascertainable. Every discontinuity that can be detected and counted is an addition to knowledge. It not only means the discovery of natural units instead of being dependent on artificial ones, but it throws light also on the nature of phenomena themselves.

For instance:—

The ratio between the velocity of light and the inverted square root of the product of the electric and magnetic constants was discovered by Clerk Maxwell to be 1; and a new volume of physics was by that discovery opened.

Dalton found that chemical combination occurred between quantities of different substances specified by certain whole or fractional numbers; and the atomic theory of matter sprang into substantial though at first infantile existence.

The hypothesis of Prout, which in some modified form seems likely to be substantiated, is that all atomic weights are commensurable numbers; in which case there must be a natural fundamental unit underlying, and in definite groups composing, the atoms of every form of matter.

The small number of degrees of freedom of a molecule, and the subdivision of its total energy into equal parts corresponding thereto, is a theme not indeed without difficulty but full of importance. It is responsible for the suggestion that energy too may be atomic!

Mendelejeff's series again, or the detection of a natural grouping of atomic weights in families of seven, is another example of the significance of number.

Electricity was found by Faraday to be numerically connected with quantity of matter; and the atom of electricity began its hesitating but now brilliant career.

Electricity itself—*i.e.* electric charge—strangely enough has proved itself to be atomic. There is a natural unit of electric charge, as suspected by Faraday and Maxwell and named by Johnstone Stoney. Some of the electron's visible effects were studied by Crookes in a vacuum; and its weighing and measuring by J. J. Thomson were announced to the British Association meeting at Dover in 1899—a fitting prelude to the twentieth century.

An electron is the natural unit of negative electricity, and it may not be long before the natural unit of positive electricity is found too. But concerning the nature of the positive unit there is at present some division into opposite camps. One school prefers to regard the unit of positive electricity as a homogeneous sphere, the size of an atom, in which electrons revolve in simple harmonic orbits and constitute nearly the whole effective mass. Another school, while appreciative of the simplicity and ingenuity and beauty of the details of this conception, and the skill with which it has been worked out, yet thinks the evidence more in favour of a minute central positive nucleus, or nucleus-group, of practically atomic mass; with electrons, larger—*i.e.* less concentrated—and therefore less massive than itself, revolving round it in astronomical orbits. While from yet another point of view it is insisted that positive and negative electrons can only differ skew-symmetrically, one being like the image of the other in a mirror, and that the mode in which they are grouped to form an atom remains for future discovery. But no one doubts that electricity is ultimately atomic.

Even magnetism has been suspected of being atomic, and its hypothetical unit has been named in advance the *magneton*: but I confess that here I have not been shaken out of the conservative view.

We may express all this as an invasion of number into unsuspected regions.

Biology may be said to be becoming atomic. It has long had natural units in the shape of cells and nuclei, and some discontinuity represented by body-boundaries and cell-walls; but now, in its laws of heredity as studied by Mendel, number and discontinuity are strikingly apparent among the reproductive cells, and the varieties of offspring

admit of numerical specification and prediction to a surprising extent; while modification by continuous variation, which seemed to be of the essence of Darwinism, gives place to, or at least is accompanied by, mutation, with finite and considerable and in appearance discontinuous change.

So far from Nature not making jumps, it becomes doubtful if she does anything else. Her hitherto placid course, more closely examined, is beginning to look like a kind of steeplechase.

Yet undoubtedly Continuity is the backbone of evolution, as taught by all biologists—no artificial boundaries or demarcations between species—a continuous chain of heredity from far below the amœba up to man. Actual continuity of undying germ-plasm, running through all generations, is taught likewise; though a strange discontinuity between this persistent element and its successive accessory body-plasms—a discontinuity which would convert individual organisms into mere temporary accretions or excretions, with no power of influencing or conveying experience to their generating cells—is advocated by one school.

Discontinuity does not fail to exercise fascination even in pure Mathematics. Curves are invented which have no tangent or differential coefficient, curves which consist of a succession of dots or of twists; and the theory of commensurable numbers seems to be exerting a dominance over philosophic mathematical thought as well as over physical problems.

And not only these fairly accepted results are prominent, but some more difficult and unexpected theses in the same direction are being propounded, and the atomic character of Energy is advocated. We had hoped to be honoured by the presence of Professor Planck, whose theory of the *quantum*, or indivisible unit or atom of energy, excites the greatest interest, and by some is thought to hold the field.

Then again Radiation is showing signs of becoming atomic or discontinuous. The corpuscular theory of radiation is by no means so dead as in my youth we thought it was. Some radiation is certainly corpuscular, and even the etherial kind shows indications, which may be misleading, that it is spotty, or locally concentrated into points, as if the wave-front consisted of detached specks or patches; or, as J. J. Thomson says, 'the wave-front must be more analogous to bright specks on a dark ground than to a uniformly illuminated surface,' thus suggesting that the Ether may be fibrous in structure, and that a wave runs along lines of electric force; as the genius of Faraday surmised might be possible in his 'Thoughts on Ray Vibrations.' Indeed Newton guessed something of the same kind, I fancy, when he superposed ether-pulses on his corpuscles.

Whatever be the truth in this matter, a discussion on Radiation, of extreme weight and interest, though likewise of great profundity and

technicality, is expected on Friday in Section A. We welcome Professor Lorentz, Dr. Arrhenius, Professor Langevin, Professor Pringsheim, and others, some of whom have been specially invited to England because of the important contributions which they have made to the subject-matter of this discussion.

Why is so much importance attached to Radiation? Because it is the best-known and longest-studied link between matter and ether, and the only property we are acquainted with that affects the unmodified great mass of ether alone. Electricity and magnetism are associated with the modifications or singularities called electrons: most phenomena are connected still more directly with matter. Radiation, however, though excited by an accelerated electron, is subsequently let loose in the ether of space, and travels as a definite thing at a measurable and constant pace—a pace independent of everything so long as the ether is free, unmodified and unloaded by matter. Hence radiation has much to teach us, and we have much to learn concerning its nature.

How far can the analogy of granular, corpuscular, countable, atomic, or discontinuous things be pressed? There are those who think it can be pressed very far. But to avoid misunderstanding let me state, for what it may be worth, that I myself am an upholder of *ultimate* Continuity, and a fervent believer in the Ether of Space.

We have already learnt something about the ether; and although there may be almost as many varieties of opinion as there are people qualified to form one, in my view we have learnt as follows:

The Ether is the universal connecting medium which binds the universe together, and makes it a coherent whole instead of a chaotic collection of independent isolated fragments. It is the vehicle of transmission of all manner of force, from gravitation down to cohesion and chemical affinity; it is therefore the storehouse of potential energy.

Matter moves, but Ether is strained.

What we call elasticity of matter is only the result of an alteration of configuration due to movement and readjustment of particles, but all the strain and stress are in the ether. The ether itself does not move, that is to say it does not move in the sense of locomotion, though it is probably in a violent state of rotational or turbulent motion in its smallest parts; and to that motion its exceeding rigidity is due.

As to its density, it must be far greater than that of any form of matter, millions of times denser than lead or platinum. Yet matter moves through it with perfect freedom, without any friction or viscosity. There is nothing paradoxical in this: viscosity is not a function of density; the two are not necessarily connected. When a solid moves through an alien fluid it is true that it acquires a spurious or apparent extra inertia from the fluid it displaces; but, in the case

of matter and ether, not only is even the densest matter excessively porous and discontinuous, with vast interspaces in and among the atoms, but the constitution of matter is such that there appears to be no displacement in the ordinary sense at all; the ether is itself so modified as to *constitute* the matter in some way. Of course that portion moves, its inertia is what we observe, and its amount depends on the potential energy in its associated electric field, but the motion is not like that of a foreign body, it is that of some inherent and merely individualised portion of the stuff itself. Certain it is that the ether exhibits no trace of viscosity.[1]

Matter in motion, Ether under strain, constitute the fundamental concrete things we have to do with in physics. The first pair represent kinetic energy, the second potential energy; and all the activities of the material universe are represented by alternations from one of these forms to the other.

Whenever this transference and transformation of energy occur, work is done, and some effect is produced, but the energy is never diminished in quantity: it is merely passed on from one body to another, always from ether to matter or vice versa,—except in the case of radiation, which simulates matter—and from one form to another.

The forms of energy can be classified as either a translation, a rotation, or a vibration, of pieces of matter of different sizes, from stars and planets down to atoms and electrons; or else an etherial strain which in various different ways is manifested by the behaviour of such masses of matter as appeal to our senses.[2]

Some of the facts responsible for the suggestion that energy is atomic seem to me to depend on the discontinuous nature of the structure of a material atom, and on the high velocity of its constituent particles. The apparently discontinuous emission of radiation is, I believe, due to features in the real discontinuity of matter. Disturbances inside an atom appear to be essentially catastrophic; a portion is liable to be ejected with violence. There appears to be a critical velocity below which ejection does not take place; and, when it does, there also occurs a sudden re-arrangement of parts which is presumably responsible for some perceptible etherial radiation. Hence it is, I suppose. that radiation comes off in gushes or bursts; and hence it appears to consist of indivisible units. The occasional phenomenon of new stars, as compared with the steady orbital motion of the millions of recognised bodies, may be suggested as an astronomical analogue.

The hypothesis of *quanta* was devised to reconcile the law that

[1] For details of my experiment on this subject see *Phil. Trans. Roy. Soc.* for 1893 and 1897; or a very abbreviated reference to it, and to the other matters above-mentioned, in my small book *The Ether of Space*.

[2] See, in the *Philosophical Magazine* for 1879, my article on a Classification of the forms of energy.

the energy of a group of colliding molecules must in the long run be equally shared among all their degrees of freedom, with the observed fact that the energy is really shared into only a small number of equal parts. For if vibration-possibilities have to be taken into account, the number of degrees of molecular freedom must be very large, and energy shared among them ought soon to be all frittered away; whereas it is not. Hence the idea is suggested that minor degrees of freedom are initially excluded from sharing the energy, because they cannot be supplied with less than one atom of it.

I should prefer to express the fact by saying that the ordinary encounters of molecules are not of a kind able to excite atomic vibrations, or in any way to disturb the ether. Spectroscopic or luminous vibrations of an atom are excited only by an exceptionally violent kind of collision, which may be spoken of as chemical clash; the ordinary molecular orbital encounters, always going on at the rate of millions a second, are ineffective in that respect, except in the case of phosphorescent or luminescent substances. That common molecular deflexions *are* ineffective is certain, else all the energy would be dissipated or transferred from matter into the ether; and the reasonableness of their radiative inefficiency is not far to seek, when we consider the comparatively leisurely character of molecular movements, at speeds comparable with the velocity of sound. Admittedly, however, the effective rigidity of molecules must be complete, otherwise the sharing of energy must ultimately occur. They do not seem able to be set vibrating by anything less than a certain minimum stimulus; and that is the basis for the theory of *quanta*.

Quantitative applications of Planck's theory, to elucidate the otherwise shaky stability of the astronomically constituted atom, have been made; and the agreement between results so calculated and those observed, including a determination of series of spectrum lines, is very remarkable. One of the latest contributions to this subject is a paper by Dr. Bohr in the 'Philosophical Magazine' for July this year.

To show that I am not exaggerating the modern tendency towards discontinuity, I quote, from M. Poincaré's 'Dernières Pensées,' a proposition which he announces in italics as representing a form of Professor Planck's view of which he apparently approves:—

> 'A physical system is susceptible of a finite number only of distinct conditions; it jumps from one of these conditions to another without passing through a continuous series of intermediate conditions.'

Also this from Sir Joseph Larmor's Preface to Poincaré's 'Science and Hypothesis':—

> 'Still more recently it has been found that the good Bishop

Berkeley's logical jibes against the Newtonian ideas of fluxions and limiting ratios cannot be adequately appeased in the rigorous mathematical conscience until our apparent continuities are resolved mentally into discrete aggregates which we only partially apprehend. The irresistible impulse to atomise everything thus proves to be not merely a disease of the physicist: a deeper origin, in the nature of knowledge itself, is suggested.'

One very valid excuse for this prevalent attitude is the astonishing progress that has been made in actually seeing, or almost seeing, the molecules, and studying their arrangement and distribution.

The laws of gases have been found to apply to emulsions and to fine powders in suspension, of which the Brownian movement has long been known. This movement is caused by the orthodox molecular bombardment, and its average amplitude exactly represents the theoretical mean free path calculated from the 'molecular weight' of the relatively gigantic particles. The behaviour of these microscopically visible masses corresponds closely and quantitatively with what could be predicted for them as fearfully heavy atoms, on the kinetic theory of gases; they may indeed be said to constitute a gas with a gram-molecule as high as 200,000 tons; and, what is rather important as well as interesting, they tend visibly to verify the law of equipartition of energy even in so extreme a case, when that law is properly stated and applied.

Still more remarkable—the application of X-rays to display the arrangement of molecules in crystals, and ultimately the arrangement of atoms in molecules, as initiated by Professor Laue with Drs. Friedrich and Knipping, and continued by Professor Bragg and his son and by Dr. Tutton, constitute a series of researches of high interest and promise. By this means many of the theoretical anticipations of our countryman, Mr. William Barlow, and—working with him—Professor Pope, as well as of those distinguished crystallographers von Groth and von Fedorow, have been confirmed in a striking way. These brilliant researches, which seem likely to constitute a branch of Physics in themselves, and which are being continued by Messrs. Moseley and C. G. Darwin, and by Mr. Keene and others, may be called an apotheosis of the atomic theory of matter.

One other controversial topic I shall touch upon in the domain of physics, though I shall touch upon it lightly, for it is not a matter for easy reference as yet. If the 'Principle of Relativity' in an extreme sense establishes itself, it seems as if even Time would become discontinuous and be supplied in atoms, as money is doled out in pence or centimes instead of continuously;—in which case our customary existence will turn out to be no more really continuous than

the events on a kinematograph screen;—while that great agent of continuity, the Ether of Space, will be relegated to the museum of historical curiosities.

In that case differential equations will cease to represent the facts of nature; they will have to be replaced by Finite Differences, and the most fundamental revolution since Newton will be inaugurated.

Now in all the debatable matters of which I have indicated possibilities I want to urge a conservative attitude. I accept the new experimental results on which some of these theories—such as the Principle of Relativity—are based, and am profoundly interested in them, but I do not feel that they are so revolutionary as their propounders think. I see a way to retain the old and yet embrace the new, and I urge moderation in the uprooting and removal of landmarks.

And of these the chief is Continuity. I cannot imagine the exertion of mechanical force across empty space, no matter how minute; a continuous medium seems to me essential. I cannot admit discontinuity in either Space or Time, nor can I imagine any sort of experiment which would justify such a hypothesis. For surely we must realise that we know nothing experimental of either space or time, we cannot modify them in any way. We make experiments on bodies, and only on bodies, using 'body' as an exceedingly general term.

We have no reason to postulate anything but continuity for space and time. We cut them up into conventional units for convenience' sake, and those units we can count; but there is really nothing atomic or countable about the things themselves. We can count the rotations of the earth, or the revolutions of an electron, or the vibrations of a pendulum, or the waves of light. All these are concrete and tractable physical entities; but space and time are ultimate data, abstractions based on experience. We know them through motion, and through motion only, and motion is essentially continuous. We ought clearly to discriminate between things themselves and our mode of measuring them. Our measures and perceptions may be affected by all manner of incidental and trivial causes, and we may get confused or hampered by our own movement; but there need be no such complication in things themselves, any more than a landscape is distorted by looking at it through an irregular window-pane or from a travelling coach. It is an ancient and discarded fable that complications introduced by the motion of an observer are real complications belonging to the outer universe.

Very well, then, what about the Ether? Is that in the same predicament? Is that an abstraction, or a mere convention, or is it a concrete physical entity on which we can experiment?

Now it has to be freely admitted that it is exceedingly difficult to make experiments on the ether. It does not appeal to sense, and

we know no means of getting hold of it. The one thing we know metrical about it is the velocity with which it can transmit transverse waves. That is clear and definite, and thereby, to my judgment, it proves itself a physical agent; not indeed tangible or sensible, but yet concretely real.

But it does elude our laboratory grasp. If we rapidly move matter through it, hoping to grip it and move it too, we fail: there is no mechanical connection. And even if we experiment on light we fail too. So long as transparent matter is moving relatively to us, light can be affected inside that matter; but when matter is relatively stationary to matter nothing observable takes place, however fast things may be moving, so long as they move together.

Hence arises the idea that motion with respect to Ether is meaningless: and the fact that only relative motion of pieces of matter with respect to each other has so far been observed is the foundation of the Principle of Relativity. It sounds simple enough as thus stated, but in its developments it is an ingenious and complicated doctrine, embodying surprising consequences, which have been worked out by Professor Einstein and his disciples with consummate ingenuity.

What have I to urge against it? Well, in the first place, it is only in accordance with common sense that no effect of the first order can be observed without relative motion of matter. An Ether-stream through our laboratories is optically and electrically undetectable, at least as regards first-order observation; this is clearly explained for general readers in my book 'The Ether of Space,' Chapter IV. (Also in *Nature*, vol. 46, p. 497.) But the Principle of Relativity says more than that; it says that no effect of any order of magnitude can ever be observed without the relative motion of matter.

The truth underlying this doctrine is that absolute motion without reference to *anything* is unmeaning. But the narrowing down of 'anything' to mean any piece of matter is illegitimate. The nearest approach to absolute motion that we can physically imagine is motion through or with respect to the Ether of Space. It is natural to assume that the Ether is on the whole stationary, and to use it as a standard of rest; in that sense motion with reference to it may be called absolute, but in no other sense.

The Principle of Relativity claims that we can never ascertain such motion: in other words it practically or pragmatically denies the existence of the Ether. Every one of our scientifically observed motions, it says, are of the same nature as our popularly observed ones, viz., motion of pieces of matter relatively to each other; and that is all that we can ever know. Everything goes on—says the Principle of Relativity—as if the Ether did not exist.

Now the facts are that no motion with reference to the ether

alone has ever yet been observed: there are always curious compensating effects which just cancel out the movement-terms and destroy or effectively mask any phenomenon that might otherwise be expected. When matter moves past matter observation can be made; but, even so, no consequent locomotion of ether, outside the actually moving particles, can be detected.

It is sometimes urged that rotation is a kind of absolute motion that can be detected, even in isolation. It can so be detected, as Newton pointed out; but in cases of rotation matter on one side the axis is moving in the opposite direction to matter on the other side of the axis; hence rotation involves relative material motion, and therefore can be observed.

To detect motion through ether we must use an etherial process. We may use radiation, and try to compare the speeds of light along or across the motion; or we might try to measure the speed, first with the motion, and then against it. But how are we to make the comparison? If the time of emission from a distant source is given by a distant clock, that clock must be observed through a telescope, that is by a beam of light; which is plainly a compensating process. Or the light from a neighbouring source can be sent back to us by a distant mirror; when again there will be compensation. Or the starting of light from a distant terrestrial source may be telegraphed to us, either with a wire or without; but it is the ether that conveys the message in either case, so again there will be compensation. Electricity, Magnetism, and Light, are all effects of the ether.

Use Cohesion, then; have a rod stretching from one place to another, and measure that. But cohesion is transmitted by the ether too, if, as believed, it is the universal binding medium. Compensation is likely; compensation can, on the electrical theory of matter, be predicted.

Use some action not dependent on Ether, then. Very well, where shall we find it?

To illustrate the difficulty I will quote a sentence from Sir Joseph Larmor's paper before the International Congress of Mathematicians at Cambridge last year:—

> 'If it is correct to say with Maxwell that all radiation is an electrodynamic phenomenon, it is equally correct to say with him that all electrodynamic relations between material bodies are established by the operation, on the molecules of those bodies, of fields of force which are propagated in free space as radiation and in accordance with the laws of radiation, from one body to the other.'

The fact is we are living in an epoch of some very comprehensive

generalisations. The physical discovery of the twentieth century, so far, is the Electrical Theory of Matter. This is the great new theory of our time; it was referred to, in its philosophical aspect, by Mr. Balfour in his Presidential Address at Cambridge in 1904. We are too near it to be able to contemplate it properly; it has still to establish itself and to develop in detail, but I anticipate that in some form or other it will prove true.[3]

Here is a briefest possible summary of the first chapter (so to speak) of the Electrical Theory of Matter.

(1) Atoms of Matter are composed of electrons,—of positive and negative electric charges.

(2) Atoms are bound together into molecules by chemical affinity, which is intense electrical attraction at ultra-minute distances.

(3) Molecules are held together by cohesion, which I for one regard as residual or differential chemical affinity over molecular distances.

(4) Magnetism is due to the locomotion of electrons. There is no magnetism without an electric current, atomic or otherwise. There is no electric current without a moving electron.

(5) Radiation is generated by every accelerated electron, in amount proportional to the square of its acceleration; and there is no other kind of radiation, except indeed a corpuscular kind; but this depends on the velocity of electrons, and therefore again can only be generated by their acceleration.

The theory is bound to have curious consequences; and already it has contributed to some of the uprooting and uncertainty that I speak of. For, if it be true, every material interaction will be electrical, *i.e.*, etherial; and hence arises our difficulty. Every kind of force is transmitted by the ether, and hence, so long as all our apparatus is travelling together at one and the same pace, we have no chance of detecting the motion. That is the strength of the Principle of Relativity. The changes are not zero, but they cancel each other out of observation. (*Nature*, vol. 46, page 165, 1892.)

Many forms of statement of the famous Michelson-Morley experiment are misleading. It is said to prove that the time taken by light to go with the ether stream is the same as that taken to go against or across it. It does not show that. What it shows is that the time taken by light to travel to and fro on a measured interval fixed on a

[3] For a general introductory account of the electrical theory of matter my Romanes lecture for 1903 (Clarendon Press) may be referred to.

rigid block of matter is independent of the aspect of that block with respect to any motion of the earth through space. A definite and most interesting result: but it may be, and often is, interpreted loosely and too widely.

It is interpreted too widely, as I think, when Professor Einstein goes on to assume that no non-relative motion of matter can be ever observed even when *light* is brought into consideration. The relation of light to matter is very curious. The wave front of a progressive wave simulates many of the properties of matter. It has energy, it has momentum, it exerts force, it sustains reaction. It has been described as a portion of the mass of a radiating body,—which gives it a curiously and unexpectedly corpuscular 'feel.' But it has a definite velocity. Its velocity in space relative to the ether is an absolute constant independent of the motion of the source. This would not be true for corpuscular light.

Hence I hold that here is something with which our own motion may theoretically be compared; and I predict that our motion through the ether will some day be detected by the help of this very fact,—by comparing our speed with that of light: though the old astronomical aberration, which seemed to make the comparison easy, failed to do so quite simply, because it is complicated by the necessity of observing the position of a distant source, in relation to which the earth is moving. If the source and observer are moving together there is no possibility of observing aberration. Nevertheless I maintain that when matter is moving near a beam of light we may be able to detect the motion. For the velocity of light in space is no function of the velocity of the source, nor of matter near it; it is quite unaffected by motion of source or receiver. Once launched it travels in its own way. If we are travelling to meet it, it will be arriving at us more quickly; if we travel away from it, it will reach us with some lag. That is certain; and observation of the acceleration or retardation is made by aid of Jupiter's satellites. We have there the dial of a clock, to or from which we advance or recede periodically. It gains while we approach it, it loses while we recede from it, it keeps right time when we are stationary or only moving across the line of sight.

But then of course it does not matter whether Jupiter is standing still and we are moving, or *vice versa*: it is a case of relative motion of matter again. So it is if we observe a Doppler effect from the right and left hand limbs of the rotating sun. True, and if we are to permit no relative motion of matter we must use a terrestrial source, clamped to the earth as our receiver is. And now we shall observe nothing.

But not because there is nothing to observe. Lag must really occur if we are running away from the light, even though the source is running after us at the same pace: unless we make the assumption,—

true only for corpuscular light,—that the velocity of light is not an absolute thing, but is dependent on the speed of the source. With corpuscular light there is nothing to observe; with wave light there is something, but we cannot observe it.

But if the whole solar system is moving through the ether I see no reason why the relative ether drift should not be observed by a different residual effect in connection with Jupiter's satellites or the right and left limbs of the sun. The effect must be too small to observe without extreme precision, but theoretically it ought to be there. Inasmuch however as relative motion of matter with respect to the observer is involved in these effects, it may be held that the detection of a uniform drift of the solar system in this way is not contrary to the Principle of Relativity. It is contrary to some statements of that principle; and the cogency of those statements breaks down, I think, whenever they include the velocity of light; because there we really have something absolute (in the only sense in which the term can have a physical meaning) with which we can compare our own motion, when we have learnt how.

But in ordinary astronomical translation—translation as of the earth in its orbit—all our instruments, all our standards, the whole contents of our laboratory, are moving at the same rate in the same direction; under those conditions we cannot expect to observe anything. Clerk Maxwell went so far as to say that if every particle of matter simultaneously received a graduated blow so as to produce a given constant acceleration all in the same direction, we should be unaware of the fact. He did not then know all that we know about radiation. But apart from that, and limiting ourselves to comparatively slow changes of velocity, our standards will inevitably share whatever change occurs. So far as observation goes, everything will be practically as if no change had occurred at all;—though that may not be the truth. All that experiment establishes is that there have so far always been compensations; so that the attempt to observe motion through the ether is being given up as hopeless.

Surely, however, the minute and curious compensations cannot be accidental; they must be necessary? Yes, they are necessary; and I want to say why. Suppose the case were one of measuring thermal expansion; and suppose everything had the same temperature and the same expansibility; our standards would contract or expand with everything else, and we could observe nothing; but expansion would occur nevertheless. That is obvious, but the following assertion is not so obvious. If everything in the Universe had the same temperature, no matter what that temperature was, nothing would be visible at all; the external world, so far as vision went, would not appear to exist.

Visibility depends on radiation, on differential radiation. We must have differences to appeal to our senses; they are not constructed for uniformity.

It is the extreme omnipresence and uniformity and universal agency of the ether of space that makes it so difficult to observe. To observe anything you must have differences. If all actions at a distance are conducted at the same rate through the ether, the travel of none of them can be observed. Find something not conveyed by the ether and there is a chance. But then every physical action is transmitted by the ether, and in every case by means of its transverse or radiation-like activity.

Except perhaps Gravitation. That may give us a clue some day, but at present we have not been able to detect its speed of transmission at all. No plan has been devised for measuring it. Nothing short of the creation or destruction of matter seems likely to serve: creation or destruction of the gravitational unit, whether it be an atom or an electron or whatever it is. Most likely the unit of weight is an electron, just as the unit of mass is.

The so-called non-Newtonian Mechanics, with mass and shape a function of velocity, is an immediate consequence of the electrical theory of matter. The dependence of inertia and shape on speed is a genuine discovery and, I believe, a physical fact. The Principle of Relativity would reduce it to a conventional fiction. It would seek to replace this real change in matter by imaginary changes in time. But surely we must admit that Space and Time are essentially unchangeable: they are not at the disposal even of mathematicians; though it is true that Pope Gregory, or a Daylight-saving Bill, can play with our units, can turn the 3rd of October in any one year into the 14th, or can make the sun South sometimes at eleven o'clock, sometimes at twelve [1]

But the changes of dimension and mass due to velocity are not conventions but realities: so I urge, on the basis of the electrical theory of matter. The Fitzgerald-Lorentz hypothesis I have an affection for. I was present at its birth. Indeed I assisted at its birth; for it was in my study at 21 Waverley Road, Liverpool, with Fitzgerald in an armchair, and while I was enlarging on the difficulty of reconciling the then new Michelson experiment with the theory of astronomical aberration and with other known facts, that he made his brilliant surmise:—'Perhaps the stone slab was affected by the motion.' I

[1] In the historical case of Governmental interference with the calendar no wonder the populace rebelled. Surely someone might have explained to the authorities that dropping leap-year for the greater part of a century would do all that was wanted, and that the horrible inconvenience of upsetting all engagements and shortening a single year by eleven days could be avoided.

rejoined that it was a 45° shear that was needed. To which he replied, 'Well, that's all right,—a simple distortion.' And very soon he said, 'And I believe it occurs, and that the Michelson experiment demonstrates it.' A shortening long-ways or a lengthening cross-ways would do what was wanted. (See *Nature* for June 16, 1892, p. 165.)

And is such a hypothesis gratuitous? Not at all: in the light of the electrical theory of matter such an effect ought to occur. The amount required by the experiment, and given by the theory, is equivalent to a shrinkage of the earth's diameter by rather less than three inches, in the line of its orbital motion through the ether of space. An oblate spheroid with the proper excentricity has all the simple geometrical properties of a stationary sphere; the excentricity depends in a definite way on speed, and becomes considerable as the velocity of light is approached.

All this Professors Lorentz and Larmor very soon after, and quite independently, perceived; though this is only one of the minor achievements in the electrical theory of matter which we owe to our distinguished visitor, Professor H. A. Lorentz.

The key of the position, to my mind, is the nature of cohesion. I regard cohesion as residual chemical affinity, a balance of electrical attraction over repulsion between groups of alternately charged molecules. Lateral electrical attraction is diminished by motion; so is lateral electric repulsion. In cohesion both are active, and they nearly balance. At anything but molecular distance they quite balance, but at molecular distance attraction predominates. It is the diminution of the predominant partner that will be felt. Hence while longitudinal cohesion, or cohesion in the direction of motion, remains unchanged, lateral cohesion is less; so there will be distortion, and a unit cube x y z moving along x with velocity u becomes a parallelopiped with sides $1/k^2$, k, k; where $1/k^6=1-u^2/v^2$.[5]

The electrical theory of matter is a positive achievement, and has positive results. By its aid we make experiments which throw light upon the relation between matter and the Ether of Space. The Principle of Relativity, which seeks to replace it, is a principle of negation, a negative proposition, a statement that observation of certain facts can never be made, a denial of any relation between matter and ether, a virtual denial that the ether exists. Whereas if we admit the real changes that go on by reason of rapid motion, a

[5] Different modes of estimating the change give slightly different results; some involve a compression as well as a distortion—in fact the strain associated with the name of Thomas Young; the details are rather complicated and this is not the place to discuss them. A pure distortion, as specified in the text, is simplest; it appears to be in accord with all the experimental facts—including some careful measurements by Bucherer,—and I rather expect it to survive.

whole field is open for discovery; it is even possible to investigate the changes in shape of an electron—appallingly minute though it is—as it approaches the speed of light; and properties belonging to the Ether of Space, evasive though it be, cannot lag far behind.

Speaking as a physicist, I must claim the Ether as peculiarly our own domain. The study of molecules we share with the chemist, and matter in its various forms is investigated by all men of science, but a study of the ether of space belongs to physics only. I am not alone in feeling the fascination of this portentous entity. Its curiously elusive and intangible character, combined with its universal and unifying permeance, its apparently infinite extent, its definite and perfect properties, make the ether the most interesting as it is by far the largest and most fundamental ingredient in the material cosmos.

As Sir J. J. Thomson said at Winnipeg:—

> 'The ether is not a fantastic creation of the speculative philosopher; it is as essential to us as the air we breathe. . . . The study of this all-pervading substance is perhaps the most fascinating and important duty of the physicist.'

Matter it is not, but material it is; it belongs to the material universe and is to be investigated by ordinary methods. But to say this is by no means to deny that it may have mental and spiritual functions to subserve in some other order of existence, as Matter has in this.

The ether of space is at least the great engine of continuity. It may be much more, for without it there could hardly be a material universe at all. Certainly, however, it is essential to continuity; it is the one all-permeating substance that binds the whole of the particles of matter together. It is the uniting and binding medium without which, if matter could exist at all, it could exist only as chaotic and isolated fragments: and it is the universal medium of communication between worlds and particles. And yet it is possible for people to deny its existence, because it is unrelated to any of our senses, except sight,—and to that only in an indirect and not easily recognised fashion.

To illustrate the thorough way in which we may be unable to detect what is around us unless it has some link or bond which enables it to make appeal, let me make another quotation from Sir J. J. Thomson's Address at Winnipeg in 1909. He is leading up to the fact that even single atoms, provided they are fully electrified with the proper atomic charge, can be detected by certain delicate instruments,—their field of force bringing them within our ken—whereas a whole crowd of unelectrified ones would escape observation.

> 'The smallest quantity of unelectrified matter ever detected is probably that of neon, one of the inert gases of the atmosphere.

Professor Strutt has shown that the amount of neon in 1/20 of a cubic centimetre of the air at ordinary pressures can be detected by the spectroscope; Sir William Ramsay estimates that the neon in the air only amounts to one part of neon in 100,000 parts of air, so that the neon in 1/20 of a cubic centimetre of air would only occupy at atmospheric pressure a volume of half a millionth of a cubic centimetre. When stated in this form the quantity seems exceedingly small, but in this small volume there are about ten million million molecules. Now the population of the earth is estimated at about fifteen hundred millions, so that the smallest number of molecules of neon we can identify is about 7,000 times the population of the earth. In other words, if we had no better test for the existence of a man than we have for that of an unelectrified molecule we should come to the conclusion that the earth is uninhabited.'

The parable is a striking one, for on these lines it might legitimately be contended that we have no right to say positively that even space is uninhabited. All we can safely say is that we have no means of detecting the existence of non-planetary immaterial dwellers, and that unless they have some link or bond with the material they must always be physically beyond our ken. We may therefore for practical purposes legitimately treat them as non-existent until such link is discovered, but we should not dogmatise about them. True agnosticism is legitimate, but not the dogmatic and positive and gnostic variety.

For I hold that Science is incompetent to make comprehensive denials, even about the Ether, and that it goes wrong when it makes the attempt. Science should not deal in negations: it is strong in affirmations, but nothing based on abstraction ought to presume to deny outside its own region. It often happens that things abstracted from and ignored by one branch of science may be taken into consideration by another:—

Thus, Chemists ignore the Ether.

Mathematicians may ignore experimental difficulties.

Physicists ignore and exclude live things.

Biologists exclude Mind and Design.

Psychologists may ignore human origin and human destiny.

Folk-lore students and comparative Mythologists need not trouble about what modicum of truth there may be in the legends which they are collecting and systematising.

And Microscopists may ignore the stars.

Yet none of these ignored things should be denied.

Denial is no more infallible than assertion. There are cheap and

easy kinds of scepticism, just as there are cheap and easy kinds of dogmatism; in fact scepticism can become viciously dogmatic, and science has to be as much on its guard against personal predilection in the negative as in the positive direction. An attitude of universal denial may be very superficial.

> 'To doubt everything or to believe everything are two equally convenient solutions; both dispense with the necessity of reflection.'

All intellectual processes are based on abstraction. For instance, History must ignore a great multitude of facts in order to treat any intelligently: it selects. So does Art; and that is why a drawing is clearer than reality. Science makes a diagram of reality, displaying the works, like a skeleton clock. Anatomists dissect out the nervous system, the blood vessels, and the muscles, and depict them separately, —there must be discrimination for intellectual grasp,—but in life they are all merged and co-operating together; they do not really work separately, though they may be studied separately. A scalpel discriminates: a dagger or a bullet crashes through everything. That is life,—or rather death. The laws of nature are a diagrammatic framework, analysed or abstracted out of the full comprehensiveness of reality.

Hence it is that Science has no authority in denials. To deny effectively needs much more comprehensive knowledge than to assert. And abstraction is essentially not comprehensive: one cannot have it both ways. Science employs the methods of abstraction and thereby makes its discoveries.

The reason why some physiologists insist so strenuously on the validity and self-sufficiency of the laws of physics and chemistry, and resist the temptation to appeal to unknown causes—even though the guiding influence and spontaneity of living things are occasionally conspicuous as well as inexplicable—is that they are keen to do their proper work; and their proper work is to pursue the laws of ordinary physical Energy into the intricacies of 'colloidal electrolytic structures of great chemical complexity' and to study its behaviour there.

What we have clearly to grasp, on their testimony, is that for all the terrestrial manifestations of life the ordinary physical and chemical processes have to serve. There are not new laws for living matter, and old laws for non-living; the laws are the same; or if ever they differ, the burden of proof rests on him who sustains the difference. The conservation of energy, the laws of chemical combination, the laws of electric currents, of radiation, etc., etc.,—all the laws of Chemistry and Physics,—may be applied without hesitation in the Organic domain. Whether they are sufficient is open to question, but as far as they go

they are necessary; and it is the business of the physiologist to seek out and demonstrate the action of those laws in every vital action.

This is clearly recognised by the leaders, and in the definition of Physiology by Burdon Sanderson he definitely limited it to the study of 'ascertainable characters of a chemical and physical type.' In his Address to the Sub-section of Anatomy and Physiology at York in 1881 he spoke as follows:—

> 'It would give you a true idea of the nature of the great advance which took place about the middle of this century if I were to define it as the epoch of the death of "vitalism." Before that time even the greatest biologists—*e.g.* J. Müller—recognised that the knowledge biologists possessed both of vital and physical phenomena was insufficient to refer both to a common measure. The method, therefore, was to study the processes of life in relation to each other only. Since that time it has become fundamental in our science not to regard any vital process as understood at all unless it can be brought into relation with physical standards, and the methods of physiology have been based exclusively on this principle. The most efficient cause [conducing to the change] was the progress which had been made in physics and chemistry, and particularly those investigations which led to the establishment of the doctrine of the Conservation of Energy.' . . . .
>
> 'Investigators who are now working with such earnestness in all parts of the world for the advance of physiology, have before them a definite and well-understood purpose, that purpose being to acquire an exact knowledge of the chemical and physical processes of animal life and of the self-acting machinery by which they are regulated for the general good of the organism. The more singly and straightforwardly we direct our efforts to these ends, the sooner we shall attain to the still higher purpose—the effectual application of our knowledge for the increase of human happiness.'

Professor Gotch, whose recent loss we have to deplore, puts it more strongly:—

> 'It is essentially unscientific,' he says, 'to say that any physiological phenomenon is caused by vital force.'

I observe that by some critics I have been called a vitalist, and in a sense I am; but I am not a vitalist if vitalism means an appeal to an undefined 'vital force' (an objectionable term I have never thought of using) as against the laws of Chemistry and Physics. Those laws must be supplemented, but need by no means be superseded. The

business of science is to trace out their mode of action everywhere, as far and as fully as possible; and it is a true instinct which resents the mediæval practice of freely introducing spiritual and unknown causes into working science. In science an appeal to occult qualities must be illegitimate, and be a barrier to experiment and research generally; as, when anything is called an Act of God—and when no more is said. The occurrence is left unexplained. As an ultimate statement such a phrase may be not only true but universal in its application. But there are always proximate explanations which may be looked for and discovered with patience. So, lightning, earthquakes, and other portents are reduced to natural causes. No ultimate explanation is ever attained by science: proximate explanations only. They are what it exists for; and it is the business of scientific men to seek them.

To attribute the rise of sap to vital force would be absurd, it would be giving up the problem and stating nothing at all. The way in which osmosis acts to produce the remarkable and surprising effect is discoverable and has been discovered.

So it is always in science, and its progress began when unknown causes were eliminated and treated as non-existent. Those causes, so far as they exist, must establish their footing by direct investigation and research; carried on in the first instance apart from the long-recognised branches of science, until the time when they too have become sufficiently definite to be entitled to be called scientific. Outlandish Territories may in time be incorporated as States, but they must make their claim good and become civilised first.

It is well for people to understand this definite limitation of scope quite clearly, else they wrest the splendid work of biologists to their own confusion,—helped it is true by a few of the more robust or less responsible theorisers, among those who should be better informed and more carefully critical in their philosophising utterances.

But, as is well known, there are more than a few biologists who, when taking a broad survey of their subject, clearly perceive and teach that before all the actions of live things are fully explained some hitherto excluded causes must be postulated. Ever since the time of J. R. Mayer it has been becoming more and more certain that as regards performance of work a living thing obeys the laws of physics, like everything else; but undoubtedly it initiates processes and produces results that without it could not have occurred,—from a bird's nest to a honeycomb, from a deal box to a warship. The behaviour of a ship firing shot and shell is explicable in terms of energy, but the discrimination which it exercises between friend and foe is not so explicable. There is plenty of physics and chemistry and mechanics about every vital action, but for a complete understanding of it something beyond physics and chemistry is needed.

And life introduces an incalculable element. The vagaries of a fire or a cyclone could all be predicted by Laplace's Calculator, given the initial positions, velocities, and the law of acceleration of the molecules; but no mathematician could calculate the orbit of a common house-fly. A physicist into whose galvanometer a spider had crept would be liable to get phenomena of a kind quite inexplicable, until he discovered the supernatural, *i.e.* literally superphysical, cause. I will risk the assertion that Life introduces something incalculable and purposeful amid the laws of physics; it thus distinctly supplements those laws, though it leaves them otherwise precisely as they were and obeys them all.

We see only its effect; we do not see Life itself. Conversion of Inorganic into Organic is effected always by living organisms. The conversion under those conditions certainly occurs, and the process may be studied. Life appears necessary to the conversion; which clearly takes place under the guidance of life, though in itself it is a physical and chemical process. Many laboratory conversions take place under the guidance of life, and, but for the experimenter, would not have occurred.

Again, putrefaction, and fermentation, and purification of rivers, and disease, are not purely and solely chemical processes. Chemical processes they are, but they are initiated and conducted by living organisms. Just when medicine is becoming biological, and when the hope of making the tropical belt of the earth healthily habitable by energetic races is attracting the attention of people of power, philosophising biologists should not attempt to give their science away to Chemistry and Physics. Sections D and H and I and K are not really subservient to A and B. Biology is an independent science, and it is served, not dominated, by Chemistry and Physics.

Scientific men are hostile to superstition, and rightly so, for a great many popular superstitions are both annoying and contemptible; yet occasionally the term may be wrongly applied to practices of which the theory is unknown. To a superficial observer some of the practices of biologists themselves must appear grossly superstitious. To combat malaria Sir Ronald Ross does not indeed erect an altar; no, he oils a pond,—making libation to its presiding genii. What can be more ludicrous than the curious and evidently savage ritual, insisted on by United States Officers, at that hygienically splendid achievement the Panama Canal,—the ritual of punching a hole in every discarded tin, with the object of keeping off disease! What more absurd, again—in superficial appearance—than the practice of burning or poisoning a soil to make it extra fertile!

Biologists in their proper field are splendid, and their work arouses keen interest and enthusiasm in all whom they guide into their domain.

Most of them do their work by intense concentration, by narrowing down their scope, not by taking a wide survey or a comprehensive grasp. Suggestions of broader views and outlying fields of knowledge seem foreign to the intense worker, and he resents them. For his own purpose he wishes to ignore them, and practically he may be quite right. The folly of negation is not his, but belongs to those who misinterpret or misapply his utterances, and take him as a guide in a region where, for the time at least, he is a stranger. Not by such aid is the universe in its broader aspects to be apprehended. If people in general were better acquainted with science they would not make these mistakes. They would realise both the learning and the limitations, make use of the one and allow for the other, and not take the recipe of a practical worker for a formula wherewith to interpret the Universe.

What appears to be quite certain is that there can be no terrestrial manifestation of life without matter. Hence naturally they say, or they approve such sayings as, 'I discern in matter the promise and potency of all forms of life.' Of all terrestrial manifestations of life, certainly. How else could it manifest itself save through matter? 'I detect nothing in the organism but the laws of Chemistry and Physics,' it is said. Very well: naturally enough. That is what they are after; they are studying the physical and chemical aspects or manifestations of life. But life itself—life and mind and consciousness—they are not studying, and they exclude them from their purview. Matter is what appeals to our senses here and now; Materialism is appropriate to the material world; not as a philosophy but as a working creed, as a proximate and immediate formula for guiding research. Everything beyond that belongs to another region, and must be reached by other methods. To explain the Psychical in terms of Physics and Chemistry is simply impossible; hence there is a tendency to deny its existence, save as an epiphenomenon. But all such philosophising is unjustified, and is really bad Metaphysics.

So if ever in their enthusiasm scientific workers go too far and say that the things they exclude from study have no existence in the universe, we must appeal against them to direct experience. We ourselves are alive, we possess life and mind and consciousness, we have first-hand experience of these things quite apart from laboratory experiments. They belong to the common knowledge of the race. Births, deaths, and marriages are not affairs of the biologist, but of humanity; they went on before a single one of them was understood, before a vestige of science existed. We ourselves are the laboratory in which men of science, psychologists and others, make experiments. They can formulate our processes of digestion, and the material

concomitants of willing, of sensation, of thinking; but the hidden guiding entities they do not touch.

So also if any philosopher tells you that you do not exist, or that the external world does not exist, or that you are an automaton without free will, that all your actions are determined by outside causes and that you are not responsible,—or that a body cannot move out of its place, or that Achilles cannot catch a tortoise,—then in all those cases appeal must be made to twelve average men, unsophisticated by special studies. There is always a danger of error in interpreting experience, or in drawing inferences from it; but in a matter of bare fact, based on our own first-hand experience, we are able to give a verdict. We may be mistaken as to the nature of what we see; stars may look to us like bright specks in a dome; but the fact that we see them admits of no doubt. So also Consciousness and Will are realities of which we are directly aware, just as directly as we are of motion and force, just as clearly as we apprehend the philosophising utterances of an Agnostic. The process of seeing, the plain man does not understand; he does not recognise that it is a method of etherial telegraphy; he knows nothing of the ether and its ripples, nor of the retina and its rods and cones, nor of nerve and brain processes; but he sees and he hears and he touches, and he wills and he thinks and is conscious. This is not an appeal to the mob as against the philosopher; it is appeal to the experience of untold ages as against the studies of a generation.

How consciousness became associated with matter, how life exerts guidance over chemical and physical forces, how mechanical motions are translated into sensations,—all these things are puzzling, and demand long study. But the fact that these things are so admits of no doubt; and difficulty of explanation is no argument against them. The blind man restored to sight had no opinion as to how he was healed, nor could he vouch for the moral character of the Healer, but he plainly knew that whereas he was blind now he saw. About that fact he was the best possible judge. So it is also with 'this main miracle that thou art thou, With power on thine own act and on the world.'

But although Life and Mind may be excluded from Physiology, they are not excluded from Science. Of course not. It is not reasonable to say that things necessarily elude investigation merely because we do not knock against them. Yet the mistake is sometimes made. The ether makes no appeal to sense, therefore some are beginning to say that it does not exist. Mind is occasionally put into the same predicament. Life is not detected in the laboratory, save in its physical and chemical manifestations; but we may have to admit that it guides processes nevertheless. It may be called a catalytic agent.

To understand the action of life itself, the simplest plan is not to think of a microscopic organism, or any unfamiliar animal, but to make

use of our own experience as living beings. Any positive instance serves to stem a comprehensive denial; and if the reality of mind and guidance and plan is denied because they make no appeal to sense, then think how the world would appear to an observer to whom the existence of men was unknown and undiscoverable, while yet all the laws and activities of nature went on as they do now.

Suppose, then, that *man* made no appeal to the senses of an observer of this planet. Suppose an outside observer could see all the events occurring in the world, save only that he could not see animals or men. He would describe what he saw much as we have to describe the activities initiated by life.

If he looked at the Firth of Forth, for instance, he would see piers arising in the water, beginning to sprout, reaching across in strange manner till they actually join or are joined by pieces attracted up from below to complete the circuit (a solid circuit round the current). He would see a sort of bridge or filament thus constructed, from one shore to the other, and across this bridge insect-like things crawling and returning for no very obvious reason.

Or let him look at the Nile, and recognise the meritorious character of that river in promoting the growth of vegetation in the desert. Then let him see a kind of untoward crystallisation growing across and beginning to dam the beneficent stream. Blocks fly to their places by some kind of polar forces; 'we cannot doubt' that it is by helio- or other tropism. There is no need to go outside the laws of mechanics and physics, there is no difficulty about supply of energy—none whatever,—materials in tin cans are consumed which amply account for all the energy; and all the laws of physics are obeyed. The absence of any design, too, is manifest; for the effect of the structure is to flood an area up-stream which might have been useful, and to submerge a structure of some beauty; while down stream its effect is likely to be worse, for it would block the course of the river and waste it on the desert, were it not that fortunately some leaks develop and a sufficient supply still goes down—goes down in fact more equably than before: so that the ultimate result is beneficial to vegetation, and simulates intention.

If told concerning either of these structures that an engineer, a designer in London, called Benjamin Baker, had anything to do with it, the idea would be preposterous. One conclusive argument is final against such a superstitious hypothesis—he is not there, and a thing plainly cannot act where it is not. But although we, with our greater advantages, perceive that the right solution for such an observer would be the recognition of some unknown agency or agent, it must be admitted that an explanation in terms of a vague entity called vital force would be useless, and might be so worded as to be misleading; whereas

a statement in terms of mechanics and physics could be clear and definite and true as far as it went, though it must necessarily be incomplete.

And note that what we observe, in such understood cases, is an *Interaction* of Mind and Matter; not Parallelism nor Epiphenomenalism nor anything strained or difficult, but a straightforward utilisation of the properties of matter and energy for purposes conceived in the mind, and executed by muscles guided by acts of will.

But, it will be said, this is unfair, for we *know* that there is design in the Forth Bridge or the Nile Dam, we have seen the plans and understand the agencies at work: we know that it was conceived and guided by life and mind, it is unfair to quote this as though it could simulate an automatic process.

Not at all, say the extreme school of biologists whom I am criticising, or ought to say if they were consistent, there is nothing but Chemistry and Physics at work anywhere; and the mental activity apparently demonstrated by those structures is only an illusion, an epiphenomenon; the laws of chemistry and physics are supreme, and they are sufficient to account for everything!

Well, they account for things up to a point; they account in part for the colour of a sunset, for the majesty of a mountain peak, for the glory of animate existence. But do they account for everything completely? Do they account for our own feeling of joy and exaltation, for our sense of beauty, for the manifest beauty existing throughout nature? Do not these things suggest something higher and nobler and more joyous, something for the sake of which all the struggle for existence goes on?

Surely there must be a deeper meaning involved in natural objects. Orthodox explanations are only partial, though true as far as they go. When we examine each particoloured pinnule in a peacock's tail, or hair in a zebra's hide, and realise that the varying shades on each are so placed as to contribute to the general design and pattern, it becomes exceedingly difficult to explain how this organised co-operation of parts, this harmonious distribution of pigment cells, has come about on merely mechanical principles. It would be as easy to explain the sprouting of the cantilevers of the Forth Bridge from its piers, or the flocking of the stones of the Nile Dam by chemiotaxis. Flowers attract insects for fertilisation; and fruit tempts birds to eat it in order to carry seeds. But these explanations cannot be final. We have still to explain the insects. So much beauty cannot be necessary merely to attract their attention. We have further to explain this competitive striving towards life. Why do things struggle to exist? Surely the effort must have some significance, the development some aim. We thus reach the problem of Existence itself, and the meaning of Evolution.

The mechanism whereby existence entrenches itself is manifest, or at least has been to a large extent discovered. Natural Selection is a vera causa, so far as it goes; but if so much beauty is necessary for insects, what about the beauty of a landscape or of clouds? What utilitarian object do those subserve? Beauty in general is not taken into account by science. Very well, that may be all right, but it exists nevertheless. It is not my function to discuss it. No; but it is my function to remind you and myself that our studies do not exhaust the Universe, and that if we dogmatise in a negative direction, and say that we can reduce everything to physics and chemistry, we gibbet ourselves as ludicrously narrow pedants, and are falling far short of the richness and fullness of our human birthright. How far preferable is the reverent attitude of the Eastern Poet:—

> 'The world with eyes bent upon thy feet stands in awe with all its silent stars.'

Superficially and physically we are very limited. Our sense organs are adapted to the observation of matter; and nothing else directly appeals to us. Our nerve-muscle-system is adapted to the production of motion in matter, in desired ways; and nothing else in the material world can we accomplish. Our brain and nerve systems connect us with the rest of the physical world. Our senses give us information about the movements and arrangements of matter. Our muscles enable us to produce changes in those distributions. That is our equipment for human life; and human history is a record of what we have done with these parsimonious privileges.

Our brain, which by some means yet to be discovered connects us with the rest of the material world, has been thought partially to disconnect us from the mental and spiritual realm, to which we really belong but from which for a time and for practical purposes we are isolated. Our common or social association with matter gives us certain opportunities and facilities, combined with obstacles and difficulties which are themselves opportunities for struggle and effort.

Through matter we become aware of each other, and can communicate with those of our fellows who have ideas sufficiently like our own for them to be stimulated into activity by a merely physical process set in action by ourselves. By a timed succession of vibratory movements (as in speech and music), or by a static distribution of materials (as in writing, painting, and sculpture), we can carry on intelligent intercourse with our fellows; and we get so used to these ingenious and roundabout methods, that we are apt to think of them and their like as not only the natural but as the only possible modes of communication, and that anything more direct would disarrange the whole fabric of science.

It is clearly true that our bodies constitute the normal means of manifesting ourselves to each other while on the planet; and that if the physiological mechanism whereby we accomplish material acts is injured, the conveyance of our meaning and the display of our personality inevitably and correspondingly suffer.

So conspicuously is this the case that it has been possible to suppose that the communicating mechanism, formed and worked by us, is the whole of our existence: and that we are essentially nothing but the machinery by which we are known. We find the machinery utilising nothing but well-known forms of energy, and subject to all the laws of chemistry and physics,—it would be strange if it were not so,—and from that fact we try to draw valid deductions as to our nature, and as to the impossibility of our existing apart from and independent of these temporary modes of material activity and manifestation. We so uniformly employ them, in our present circumstances, that we should be on our guard against deception due to this very uniformity. Material bodies are all that we have any control over, are all that we are experimentally aware of; anything that we can do with these is open to us; any conclusions we can draw about them may be legitimate and true. But to step outside their province and to deny the existence of any other region because we have no sense organ for its appreciation, or because (like the Ether) it is too uniformly omnipresent for our ken, is to wrest our advantages and privileges from their proper use and apply them to our own misdirection.

But if we have learnt from science that Evolution is real, we have learnt a great deal. I must not venture to philosophise, but certainly from the point of view of science Evolution is a great reality. Surely evolution is not an illusion; surely the universe progresses in time. Time and Space and Matter are abstractions, but are none the less real: they are data given by experience; and Time is the keystone of evolution. 'Thy centuries follow each other, perfecting a small wild flower.'

We abstract from living moving Reality a certain static aspect, and we call it Matter; we abstract the element of progressiveness, and we call it Time. When these two abstractions combine, co-operate, interact, we get reality again. It is like Poynting's theorem.

The only way to refute or confuse the theory of Evolution is to introduce the subjectivity of time. That theory involves the reality of time, and it is in this sense that Prof. Bergson uses the great phrase 'Creative Evolution.'

I see the whole of material existence as a steady passage from past to future, only the single instant which we call the present being actual. The past is not non-existent however, it is stored in our memories, there

is a record of it in matter, and the present is based upon it; the future is the outcome of the present, and is the product of evolution.

Existence is like the output from a loom. The pattern, the design for the weaving, is in some sort 'there' already; but whereas our looms are mere machines, once the guiding cards have been fed into them, the Loom of Time is complicated by a multitude of free agents who can modify the web, making the product more beautiful or more ugly according as they are in harmony or disharmony with the general scheme. I venture to maintain that manifest imperfections are thus accounted for, and that *freedom* could be given on no other terms, nor at any less cost.

The ability thus to work for weal or woe is no illusion, it is a reality, a responsible power which conscious agents possess; wherefore the resulting fabric is not something preordained and inexorable, though by wide knowledge of character it may be inferred. Nothing is inexorable except the uniform progress of time; the cloth must be woven, but the pattern is not wholly fixed and mechanically calculable.

Where inorganic matter alone is concerned, there everything is determined. Wherever full consciousness has entered, new powers arise, and the faculties and desires of the conscious parts of the scheme have an effect upon the whole. It is not guided from outside but from within, and the guiding power is immanent at every instant. Of this guiding power we are a small but not wholly insignificant portion.

That evolutionary progress is real is a doctrine of profound significance, and our efforts at social betterment are justified because we are a part of the scheme, a part that has become conscious, a part that realises, however dimly, what it is doing and what it is aiming at. Planning and aiming are therefore not absent from the whole, for we are a part of the whole, and are conscious of them in ourselves.

Either we are immortal beings or we are not. We may not know our destiny, but we must have a destiny of some sort. Those who make denials are just as likely to be wrong as those who make assertions: in fact, denials are assertions thrown into negative form. Scientific men are looked up to as authorities, and should be careful not to mislead. Science may not be able to reveal human destiny, but it certainly should not obscure it. Things are as they are, whether we find them out or not; and if we make rash and false statements, posterity will detect us—if posterity ever troubles its head about us. I am one of those who think that the methods of Science are not so limited in their scope as has been thought: that they can be applied much more widely, and that the Psychic region can be studied and brought under law too. Allow us anyhow to make the attempt. Give us a fair

field. Let those who prefer the materialistic hypothesis by all means develop their thesis as far as they can; but let us try what we can do in the Psychical region, and see which wins. Our methods are really the same as theirs—the subject-matter differs. Neither should abuse the other for making the attempt.

Whether such things as intuition and revelation ever occur is an open question. There are some who have reason to say that they do. They are at any rate not to be denied off-hand. In fact, it is always extremely difficult to deny *anything* of a general character, since evidence in its favour may be only hidden and not forthcoming, especially not forthcoming at any particular age of the world's history, or at any particular stage of individual mental development. Mysticism must have its place, though its relation to Science has so far not been found. They have appeared disparate and disconnected, but there need be no hostility between them. Every kind of reality must be ascertained and dealt with by proper methods. If the voices of Socrates and of Joan of Arc represent real psychical experiences, they must belong to the intelligible universe.

Although I am speaking ex cathedra, as one of the representatives of orthodox science, I will not shrink from a personal note summarising the result on my own mind of thirty years' experience of psychical research, begun without predilection—indeed with the usual hostile prejudice. This is not the place to enter into detail or to discuss facts scorned by orthodox science, but I cannot help remembering that an utterance from this chair is no ephemeral production—it remains to be criticised by generations yet unborn, whose knowledge must inevitably be fuller and wider than our own. Your President therefore should not be completely bound by the shackles of present-day orthodoxy, nor limited to beliefs fashionable at the time. In justice to myself and my co-workers I must risk annoying my present hearers, not only by leaving on record our conviction that occurrences now regarded as occult can be examined and reduced to order by the methods of science carefully and persistently applied, but by going further and saying, with the utmost brevity, that already the facts so examined have convinced me that memory and affection are not limited to that association with matter by which alone they can manifest themselves here and now, and that personality persists beyond bodily death. The evidence—nothing new or sensational, but cumulative and demanding prolonged serious study—to my mind goes to prove that discarnate intelligence, under certain conditions, may interact with us on the material side, thus indirectly coming within our scientific ken; and that gradually we may hope to attain some understanding of the nature of a larger, perhaps etherial, existence, and of the conditions regulating intercourse across the chasm. A body of responsible in-

vestigators has even now landed on the treacherous but promising shores of a new continent.

Yes, and there is more to say than that. The methods of science are not the only way, though they are one way, of being piloted to truth. '*Uno itinere non potest perveniri ad tam grande secretum.*'

Many scientific men still feel in pugnacious mood towards Theology, because of the exaggerated dogmatism which our predecessors encountered and overcame in the past. They had to struggle for freedom to find truth in their own way; but the struggle was a deplorable necessity, and has left some evil effects. And one of them is this lack of sympathy, this occasional hostility, to other more spiritual forms of truth. We cannot really and seriously suppose that truth began to arrive on this planet a few centuries ago. The pre-scientific insight of genius—of Poets and Prophets and Saints—was of supreme value, and the access of those inspired seers to the heart of the universe was often profound. But the camp followers, the scribes and pharisees, by whatever name they may be called, had no such insight, only a vicious or a foolish obstinacy; and the prophets of a new era were stoned.

Now at last we of the new era have been victorious, and the stones are in our hands. But for us to imitate the old ecclesiastical attitude would be folly, for it cannot be sustained; humanity would ultimately rise against us, and there would come yet another period of reaction, in which for a time we should be worsted. Through the best part of two centuries there has been a revolt from religion, led by Voltaire and other great writers of that age; but let us see to it that the revolt ceases when it has gone far enough. Let us not fall into the mistake of thinking that ours is the only way of exploring the multifarious depths of the universe, and that all others are worthless and mistaken. The universe is a larger thing than we have any conception of, and no one method of search will exhaust its treasures.

Men and brethren, we are trustees of the truth of the physical universe as scientifically explored: let us be faithful to our trust. Genuine religion has its roots deep down in the heart of humanity and in the reality of things. It is not surprising that by our methods we fail to grasp it: the actions of the Deity make no appeal to any special sense, only a universal appeal; and our methods are, as we know, incompetent to detect complete uniformity. There is a Principle of Relativity here, and unless we encounter flaw or jar or change, nothing in us responds; we are deaf and blind therefore to the Immanent Grandeur, unless we have insight enough to recognise in the woven fabric of existence, flowing steadily from the loom in an infinite progress towards perfection, the ever-growing garment of a transcendent God.

..UMMARY OF THE ARGUMENT.

A marked feature of the present scientific era is the discovery of, and interest in, various kinds of Atomism; so that Continuity seems in danger of being lost sight of.

Another tendency is toward comprehensive negative generalisations from a limited point of view.

Another is to take refuge in rather vague forms of statement, and to shrink from closer examination of the puzzling and the obscure.

Another is to deny the existence of anything which makes no appeal to organs of sense, and no ready response to laboratory experiment.

Against these tendencies the author contends. He urges a belief in ultimate continuity as essential to science; he regards scientific concentration as an inadequate basis for philosophic generalisation; he believes that obscure phenomena may be expressed simply if properly faced; and he points out that the non-appearance of anything perfectly uniform and omnipresent is only what should be expected, and is no argument against its real substantial existence.

REPORTS

ON THE

STATE OF SCIENCE.

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Seismological Investigations.—Eighteenth Report of the Committee, consisting of Professor H. H. TURNER (*Chairman*), Mr. J. MILNE (*Secretary*), Mr. C. VERNON BOYS, Mr. HORACE DARWIN, Mr. F. W. DYSON, Dr. R. T. GLAZEBROOK, Mr. M. H. GRAY, Mr. R. K. GRAY, Professor J. W. JUDD, Professor C. G. KNOTT, Professor R. MELDOLA, Mr. R. D. OLDHAM, Professor J. PERRY, Mr. W. E. PLUMMER, Dr. R. A. SAMPSON, *and* Professor A. SCHUSTER. (*Drawn up by the Secretary.*)

[PLATE I.]

CONTENTS.

I. *General Notes.*

THE above Committee seek to be reappointed with a grant of 60*l*.

The expenditure in connection with seismological work during the last twelve months exceeded 300*l*. This covered the salaries of two assistants, sundry expenses connected with the Observatory at Shide in carrying out the work connected with 58 co-operating stations. Out of the above sum 200*l*. was kindly placed at the disposal of your Secretary by the Government Grant Committee of the Royal Society.

Registers.—During the last year Circulars Nos. 26 and 27 have been issued. They contain 117 pages of entries which refer to the following stations: Shide, Kew, Bidston, Stonyhurst, West Bromwich,

Guildford, Haslemere, Eskdalemuir, Paisley, Edinburgh, Cork, Ponta Delgada, Rio Tinto, San Fernando, Valetta, Cairo, Beirut, Ascension Island, St. Vincent, Cape of Good Hope, Fernando Noronha, Trinidad, Toronto, Victoria, B.C., Honolulu, Alipore, Bombay, Kodaikanal, Colombo, Seychelles, Mauritius, Adelaide, Sydney, Wellington, Christchurch.

Mr. Alan Owston, of Yokohama, kindly sends me records of earthquakes he has noted at that place; whilst Mr. Joseph Rippon, of the West India Cable Co., and Mr. Maxwell Hall, of the Weather Office, Jamaica, send records relating to that country. Observers in various parts of the world send from time to time results of their observations.

Visitors.—Baron Kujo; H. M. B. Cooke, Kolas Gold Field, South India; Dr. J. B. A. Treusch, Fanning Island; G. Hewett, Paramaribo; Sir H. B. Donkin; Lord Tennyson; Hon. A. R. D. Elliott; Officers of the Royal Fusiliers; L. F. Richardson, Eskdalemuir; G. F. C. Searle and D. L. Scott, Cambridge; Prof. W. J. Sollas and a party of geological students from Oxford; G. Owen, Liverpool University; Prof. H. H. Turner, Oxford.

Stations.

Fanning Island, 159° 40′ W., 4° N.—This is a Coral Atoll about 30 miles in circumference, no part of which is more than 1000 feet distant from the sea and not more than 10 feet above it. The instrument is in charge of Dr. J. B. A. Treusch.

Agincourt.—In the Report for 1912, page 70, this appeared as if it were a station at which there was a seismograph, which, however, is not the case. Certain of the magnetometers at the Agincourt Observatory are, however, occasionally disturbed by teleseismic motion, which did not happen with the same instruments when they were installed in Toronto.

Toronto.—The seismograph here was first installed in the old Observatory buildings. In March 1908, when these were abolished, it was temporarily erected in a dwelling-house. On September 30, 1909, it was permanently installed in the barograph room in the basement of the new Meteorological Office, which is about half a mile north of the site of the old Observatory.

Shide, Wireless Telegraphy at.—At the end of last year Mr. J. J. Shaw, of West Bromwich, very kindly installed me a wireless telegraphic system, the object of which was to obtain time signals from the Eiffel Tower or North Germany. Up to date it has worked satisfactorily, giving time to within half a second. This it has done in all kinds of weather, when it was impossible to make an observation on the sun or to obtain a Greenwich signal. The cost of an installation for this purpose is less than 10*l.*

II. *Seismic Activity in* 1910.

The following catalogue is a continuation of catalogues published in the British Association Report, 1911, p. 57, and 1912, p. 70.

The number given to an earthquake corresponds to that which is given to the same disturbance in the Shide Registers, published as British Association Circulars. The numbers with an asterisk (*) refer to earthquakes which have disturbed the whole world. Those which are not thus marked have been recorded over areas of not less than two

continents. These numbers are reproduced on the accompanying map, and those which are underlined correspond to numbers in the catalogue which carry an asterisk (*). For a description of the methods by which the position of origins has been determined see British Association Report, 1900, p. 79. When the time at which an earthquake originated is followed by plus or minus so many minutes, this means that there is a corresponding uncertainty as to the position of the origin. The names of places at which an earthquake has only been felt is followed by the letter F. If destruction has taken place it is followed by the letter D. The dotted lines on the map are the axes of troughs or ridges from which large earthquakes have originated. In the column for remarks I have made a few references to determination of origins by other investigators. Those given by Prince Galitzin are of interest from the fact that they are made from observations at a single station.[1] The determinations by Dr. Kurt Wegener depend upon observations made at three to six stations.[2]

In connection with my own observations, to make which I frequently had materials from 30 or 40 stations, it is interesting to note that these stations could sometimes be divided into groups, each of which would give different epicentres, the distances between which might be as much as six degrees. One interpretation of this is the assumption that the earthquake originated over an area the dimension of which is indicated by the distances which separate the calculated epicentres.

Date 1910	No.	Time at origin	District	Lat. and long. in degrees	Remarks. F=felt, D=destructive
Jan. 1*	2194	11.2	C_1	90 W. 24 N.	Wegener gives 82 W. 25 N., time 11.2.26. Seismograms evidently refer to two or three disturbances
„ 6	2200	19.54±2	E_3	125 E. 25 N.	Ishigakijima, Loochoo, F.
„ 8	2204	14.48±2	K_2	122 E. 35 N.	In Chili, Kwangsu and Shantung, F.
„ 15	2212	22.15	E_3	125 E. 5 N.	Mindanao, Agusan Valley, F., also Halmahera and Talaud, F
„ 19	2220	14.50±4	M_2	180 E. 4 S.	
„ 22*	2225	8.48	J	19 W. 67 N.	Galitzin gives 17 W. 68 N.
„ 23*	2228	18.48*ca*	C_2	55 W. 12 N.	St. Vincent, Georgetown, Paramaribo, F.
„ 30*	2241	3.45*ca*	F_1	168 E. 33 S.	Probably a dual earthquake.
Feb. 3	2247	16.34*ca*	F_1	168 E. 17 S.	
„ 4*	2248	14.0*ca*	F_1	168 E. 17 S.	Lifu in Loyalty Is., F. Wegener gives 177 W. 18 S., and times 13.59.7, 15.40.2, 17.36.5 and 18.32.5.

[1] See *Bulletin de l'Académie des Sciences de St.-Pétersbourg*, No. 13, 1911, p. 952.
[2] See *d. Kgl. Ges. d. Wiss. math.-phys. Kl.* 1912, Heft 3.

Date 1910	No.	Time at origin	District	Lat. and long. in degrees	Remarks. F=felt, D=destructive
Feb. 7	2255	15.40	E_3	121 E. 13 N.	N. Mindoro at Calapan, F.
„ 12*	2262	18.6	E_1	141 E. 32 N.	Central Japan, F. Galitzin gives 131.5 E. 34.58 N.
„ 13	2264	16.21*ca*	F_1, F_2, F_3	125 E. 0 N.S.	
„ 18	2267	5.11	K_6	24 E. 36 N.	Crete, Varipetro, D.
„ 27	2278	14.27*ca*	E_1, E_2, E_3	145 E. 37 N.	Central Japan, F.
„ 28*	2280	21.0±4	A_1	150 W. 47 N.	
Mar. 1	2281	11.22	M_1	170 W. 13 S.	
„ 11	2284	6.50*ca*	A_2	121 W. 38 N.	Central California, F.
„ 25	2297	15.17±2	D_1, D_2	80 W. 20 S.	Antofagasta, F.(?)
„ 25	2298	18.38	E_3	121 E. 25 N.	N. Formosa, F.
„ 30*	2301	16.55	F_1	168 E. 17 S.	
„ 31*	2302	18.13±3	L	6 W. 71 S.	
April 1		13.46	F_2	129 E. 4 S.	Ambon and Neira, F. Not recorded at Shide.
„ 8	2308	16.28±5	M_2	175 W. 2 N.	Wegener gives 171 W. 16 S. Time 16.34.7.
„ 9	2309	9.27±4	K_3	93 E. 22 N.	
„ 12*	2313	0.22	E_3	124 E. 26 N.	Formosa and Loochoo, F. Galitzin gives 122.55 E. 27.31 N. Wegener gives 122 E. 23 N. Time 0.21.6.
„ 13	2314	6.41	B	84 W. 11 N.	Costa Rica, Cartago, D.
„ 16*	2318	12.30	F_2	130 E. 5 S.	Ambon and Neira, F.
„ 17	2319	0.52*ca*	H	30 W. 30 S.(?)	Possibly 10 W. 65 S.
„ 20	2323	22.12*ca*	M_2	166 E. 8 N.	
May 1*	2329	18.30.4	F_1	170 E. 18 S.	Wegener's determination.
„ 4	2332	15.17*ca*	E_2	137 E. 17 N.	
„ 5*	2334	0.26	B	84 W. 9 N.	Costa Rica, Cartago, D.
„ 9	2335	9.47	E_1	142 E. 36 N.	E. Coast N. Japan, F.
„ 10	2337	9.29	E_3	130 E. 26 N.	
„ 10	2338	13.55	E_1	140 E. 34 N.	
„ 10*	2340	17.42*ca*	L	20 W. 55 S.	Origin doubtful.
„ 11		7.38*ca*	C_1	71 W. 18 N.	Haiti, W. Indies, D. Not recorded at Shide.
„ 11	2341	15.51*ca*	K_2	71 E. 42 N.	Talas Ala-tau in Turkestan.
„ 12	2344	3.21	E_1	141 E. 33 N.	Off Boso, E. Coast Japan, F.
„ 13*	2345	7.57*ca*	P	163 W. 48 N.	
„ 15	2348	16.3±3	F_2	122 E. 10 S.	Maoe Mere in Flores, also in Timor, F.
„ 18	2351	8.58	O	38 E. 9 S.	Tanganyika and German E. Africa, F.
„ 20*	2354	12.9*ca*	C_1	58 W. 22 N.	
„ 21	2355	7.46*ca*	K_8	12 E. 21 N.	
„ 22*	2356	6.25	E_1	145 E. 42 N.	N.E. Japan, Yokohama, Kushiro, F.
„ 23	2357	18.38	F_1	142 E. 3 N.	
„ 27	2361	11.59*ca*	K_8	9 E. 28 N.	
„ 28	2362	6.21*ca*	O	25 E. 14 S.	Rhodesia, Livingstone, F.

Date 1910	No.	Time at origin	District	Lat. and long. in degrees	Remarks. F=felt, D=destructive
May 30	2365	12.33*ca*	O	22 E. 15 N.	
„ 31*	2366	4.54	B	105 W. 10 N.	Galitzin gives 92.16 W. 23.5 N.
June 1*	2367	5.57±2	F_1	165 E. 23 S.	Wegener gives approximate origin as 170 E. 18 S. at 5.55.1.
„ 9*	2376	11.47	E_1, E_2, E_3	138 E. 28 N.	Bonin Is. and C. E. Japan, F.
„ 14	2379	19.39*ca*	H	44 W. 32 N.	
„ 16	2381	4.15	K_8	2 W. 37 N.	S. Spain, Almeria, Malaga and Algeria, D.
„ 16*	2382	6.30	F_1	166 E. 19 S.	New Caledonia and Loyalty Is., F.
„ 17	2384	5.26	E_3	128 E. 22 N.	Formosa, Pescador Is., Batanes Is., and N. Luzon, F.
„ 23	2391	2.50*ca*	E_3	121 E. 2 N.	Celebes, Posso and Paleleh, F.
„ 23	2393	18.52.5	M_2	174 W. 18 S.	Determined by Wegener.
„ 24	2394*a*	13.27.5	K_8	4 E. 36 N.	Algeria, Aumale, Tablat, D.
„ 25	2395	19.26	K_5	34 E. 41 N.	Asia Minor, Iskelib, F.
„ 26	2398	15.57	E_1	139 E. 35 N.	C. Japan, F.
„ 29*	2402	10.49*ca*	M_2	180 E.W. 15 S.	
„ 29*		14.21*ca*	M_2	178 W. 28 S.	Not recorded at Shide.
„ 29		18.9*ca*	F_2	130 E. 18 S.	Not recorded at Shide.
„ 30	2404	2.55	E_3	127 E. 4 N.	S.E. Mindanao, F.
July 2	2406	5.37	E_3	125 E. 7 N.	Agusan River, E. Mindanao, F.
„ 3	2412	9.9	A_1	135 W. 59 N.	Skagway, F.
„ 5	2415	18.30	E_3	128 E. 25 N.	Loochoo, Naha, F.
„ 7	2417	4.41	A_1	135 W. 60 N.	Skagway, F.
„ 7*	2418	8.17	F_2	108 E. 12 S.	Kediri, Soerakarta, F.
„ 8	2419	3.59	F_2	108 E. 11 S.	Madioen, Pasoeroean, F.
„ 10	2422	15.9*ca*	C_1	69 W. 16 N.	Not recorded at Shide.
„ 11	2424	20.33*ca*	F_1	170 E. 33 S.	
„ 12	2427	7.31(?)	K_2	72 E. 40 N.	Galitzin gives 35.55 N. 69.18 E. N. Afganistan, nr. Hindu Kush Mts.
„ 12	2428	21.6	F_1	163 E. 29 S.	
„ 15	2433	12.1*ca*	F_1	174 E. 23 S.	
„ 21	2443	22.17*ca*	G_1	60 E. 3 N.	
„ 22	2444	14.13	E_3	126 E. 10 N.	Surigao, F.
„ 24	2446	15.19*ca*	M_2	176 E. 7 S.	
„ 29*	2450	10.27±3	F_1	145 E. 3 N.	
Aug. 1	2454	10.43	K_6	19 E. 39 N.	Italy, South, F.
„ 1	2455	22.15*ca*	K_5	35 E. 35 N.	
„ 2	2456	2.35*ca*	K_5	21 E. 37 N.	
„ 5	2460	1.30*ca*	A_1	117 W. 48 N.	Galitzin gives 116.50 W. 39.48 N.
„ 7	2461	20.45	K_5	28 E. 38 N.	Smyrna, F.
„ 10	2465	20.16*ca*	F_2	111 E. 10 S.	
„ 11	2466	16.37	C_1	70 W. 25 N.	
„ 13	2472	21.19	K_3	90 E. 28 N.	

Date 1910		No.	Time at origin	District	Lat. and long. in degrees	Remarks. F=felt, D=destructive
Aug.	14	2473	7.33*ca*	H	32 W. 10 N.	
„	16	—	7.27*ca*	F_2	118 E. 3 S.	Not recorded at Shide.
„	17	2477	11.58	K_3	68 E. 30 N.	Galitzin gives 28.39 N. 67.10 E. Sind and Shikarpur, F.
„	21*	2486	5.20	M_3	165 E. 9 N.	
„	21	2487	16.0*ca*			In the Shide Register the date is given wrongly as Aug. 24. North of India.
Sept.	1*	2500	0.45	E_3	122 E. 21 N.	Galitzin gives 120.22 E. 23.30 N. Taito Taichu and Keelung in Formosa, also in Batanes Is., F.
„	1*	2501	14.20	E_3	122 E. 24 N.	Galitzin gives 119.54 E. 23.13 N. Taihoku Keelung, Tainan, Taichuin, Formosa, F.
„	6*	2506	19.59*ca*	D_1, D_2	82 W. 21 S.	At 20.32±2 a shock originated 5 W. 2 S. At 20.14±3 shocks were noted at Andalgala, in Catamarca, Argentina.
„	7*	2508	7.10±2	F_1	155 E. 5 S.	Wegener gives a locality near to 148 E. 4 S. at 7.10.4.
„	9*	2513	1.11	P	170 W. 45 N.	Galitzin gives 160.24 E. 45.26 N., E. of the Kuriles. Unalaska and Bogoslof Is., F.
„	14	2522	13.53	F_3	116 E. 10 S.	Soembawa and Bali, F.
„	16	2525	23.7	E_3	125 E. 19 N.	N. Luzon, F.
„	24	2533	3.23*ca*	D_1	102 W. 2 S.	Arizona, F.
„	24	2535	15·12*ca*	D_2	69 W. 35 S.	Rioja, San Juan, and Mendosa, in Argentina, F.
Oct.	2	2541	20.33 & 21.15	E_3	123 E. 12 N.	Nueva Caceres and throughout S.E. Luzon, F.
„	4*	2543	22.51*ca*	M_1	132 E. 51 S.	
„	7	2545	6.52	M_2	180 E. or W. 10 S.	
	7	2546	11.54	F_1	171 E. 18 S.	Valparaiso, F.(?)
„	7	2547	16.2	F_3	89 E. 2 N.	
„	13	2551	14.56	E_1	142 E. 38 N.	Eastern part of Central Japan, F.
„	18	2553	2.36	F_1	171 E. 19 S.	
„	20	2554	5.3*ca*	F_2	97 E. 4 S.	Padang, Bovenlanden, Sumatra, F.
„	27	2560	0.59	K_8	5 W. 35 N.	Fez in Morocco, also in Tetuan, Melilla, in Malaga, F.
„	30	2561	7.33	M_2	180 E. or W. 10 S.	
Nov.	6	2572	20.29	A_1	135 W. 53 N.	
„	9*	2578	5.57*ca*	F_1	164 E. 12 S.	Mallicolo, in New Hebrides, F.

Date 1910	No.	Time at origin	District	Lat. and long. in degrees	Remarks. F=felt, D=destructive
Nov. 10*	2579	12.11*ca*	M_2	160 E. 0 N.S.	
„ 14*	2585	7.33	E_3	120 E. 21 N.	N. Formosa, F.
„ 15*	2589	14.18*ca*	L	16 W. 62 S.	
„ 24	2594	15.41*ca*	F_2	90 E. 6 N.	
„ 25	2596*b*	19.12	E_3	125 E. 6 N.	S.E. Mindanao, Saran-gani Is., F.
„ 26*	2598	4.39*ca*	F_1	167 E. 8 S.	Not recorded at Shide.
„ 29*	2599	2.24	E_3	125 E. 25 N.	E. coast Formosa, F.
Dec. 1	2601	15.42	F_1	135 E. 0 N.S.	About this time an earthquake was recorded in Tondano in Menado.
„ 3	2603	4.5*ca*	F_1	155 E. 4 S.	Namatani, New Ireland, F.
„ 3*	2604	7.47*ca*	F_1	155 E. 4 S.	
„ 4*	2606	11.0*ca*	F_1	140 E. 10 S.	About this time an earthquake was recorded in Ambon.
„ 5	2609	16.21	E_1	150 E. 42 N.	Off N.E. Japan.
„ 10*	2612	9.25	F_1	159 E. 8 S.	Recorded in Ambon.
„ 13*	2620	11.34	O	33 E. 9 S. or 30 E. 7 S.	
„ 14*	2622	20.27*ca*	M_2	176 E. 10 N.	
„ 16*	2624	14.45	E_3	125 E. 5 N.	S. Mindanao, Sarangani Is., F.
„ 16	2625	18.50	E_3	125 E. 5 N.	S. Mindanao, Sarangani Is., F.
„ 17	2627	6.33	E_3	127 E. 4 N.	N.E. Celebes.
„ 18	2629	2.42*ca*	E_3	127 E. 4 N.	N.E. Celebes, S. Mindanao.
„ 23	2639	0.29*ca*	K_1	150 E. 62 N.	
„ 26	2640	5.34*ca*	E_2	149 E. 18 N.	
„ 27	2642	18.50*ca*	E_3	123 E. 5 N.	
„ 29	2647	13.5	E_3	122 E. 3 N.	Ambon and Mindanao, F.
„ 30*	2650	0.45*ca*	E_3	128 E. 8 N.	Mindanao, Samar, Leyte, Butuan, D.

III. *On the 443 or 452 Day Period.*

In the Report for 1912, p. 94, I pointed out that marked periods of rest followed groups of megaseisms every 443 days. Professor H. H. Turner increased this period to 452 days. December 14, 1899, is the middle of a rest period, and we find similar periods every successive 443 days. The last period—which, however, is only one of partial quiescence—was about September 3, 1909; we should expect the next one about November 20, 1910. The fact that the accompanying catalogue shows that between November 14 and 24 no large earthquake was recorded verifies the expectation.

IV. *On the Determination of the Position of Epicentres.*

In the British Association Report, 1896, p. 230, I showed by example that the distance of an epicentre could be determined from the duration of preliminary tremors. In 1911 Prince Galitzin showed that not only could a distance be determined from these precursors,

but the first of them gave the direction in which we should seek for an origin. In the British Association Report, 1900, p. 79, I gave several methods which I use when mapping the position of epicentres. These methods were dependent on a number of observations made at several more or less widely separated observatories.

As a slight addition to these I submit the following: If we have registers from a number of stations for large earthquakes it is usually easy to read the times of commencements and other phases of motion, together with the amplitudes. An inspection of the records which refer to a given earthquake shows the stations nearest to its epicentre, and any one of these should give us the distance of the same, and if we know this we can easily compute the time at which the shock originated. The difference between this and the arrival of the large waves or the maximum motion at other stations enables us to compute their respective distances from the district from which they radiated. The intersection of arcs, which I draw upon a 'black globe,' which correspond to these distances should represent the epifocal area.

I venture to mention this simple and self-evident way of procedure because it is frequently of use when other methods fail. Preliminary tremors may have been eclipsed by air tremors or microseisms, or they may have died out on their journey, with the result that the seismogram may only present very small records which represent the large waves or maximum motion.

V. *On the Variation of Earthquake Speed with the Variation in the Direction of Propagation*

In the British Association Report, 1908, p. 74, I showed that megaseismic motion was propagated from its origin farther to the east and west than it was in the direction of a meridian. One explanation for this is that in the former direction the rigidity of the propagating medium may be greater than it is in the latter direction—a suggestion that falls in line with the observations of Dr. Hecker on the gravitational influence of the moon on the crust of our world. If this hypothesis is correct it might be inferred that the velocity of propagation of earth waves would be greatest in an east-west direction.

To test this I took earthquakes Nos. 859, 860, 884, 1111, 1170, 1260, 1363, and 1632 (see British Association Report, 1912, p. 71). I selected these particular disturbances because the positions of their epicentres and times of origin were known, and also because they had been recorded at widely separated stations. For any particular earthquake the only observations considered were those made at stations the bearings of which from the epicentre were within 30 degrees of east and west or within 30 degrees of north and south. The following tables only refer to maximum motion or large waves:—

Earthquake No. 859, June 25, 1904, origin 160° E. 53° N.

					Per sec.
East-West	Bombay,	time to travel 48 m.,	distance 74°,	velocity	2·85 km.
	Mauritius,	„ 68 m.,	„ 114°,	„	3·10 km.
	Kodaikanal,	„ 48 m.,	„ 77°,	„	2·93 km.
	Calcutta,	„ 41 m.,	„ 61°,	„	2·75 km.
			Average .	. .	2·90 km.

	Station		Time		Distance		Per sec.
North-South	Shide	time to travel	48 m.,	distance	76°,	velocity	2·92 km.
	Kew,	,,	49 m.,	,,	75°,	,,	2·83 km.
	Bidston,	,,	43 m.,	,,	72°,	,,	3·09 km.
	Edinburgh	,,	44 m.,	,,	71°,	,,	2·98 km.
	Paisley,	,,	54 m.,	,,	71°,	,,	2·43 km.
	San Fernando,	,,	55 m.,	,,	90°,	,,	3·02 km.
	Wellington,	,,	80 m.,	,,	95°,	,,	2·19 km.
				Average .	.	.	2·78 km.

Earthquake No. 860, June 25, 1904, origin 160° E. 53° N.

East-West	Mauritius,	time to travel	68 m.,	distance	101°,	velocity	2·74 km.
	Calcutta,	,,	37 m.,	,,	60°,	,,	3·00 km.
	Bombay,	,,	49 m.,	,,	72°,	,,	2·72 km.
	Kodaikanal,	,,	50 m.,	,,	76°,	,,	2·81 km.
	Honolulu,	,,	26 m.,	,,	44°,	,,	3·13 km.
				Average .	.	.	2·88 km.

North-South	Shide,	time to travel	52 m.,	distance	76°,	velocity	2·70 km.
	Kew,	,,	49 m.,	,,	75°,	,,	2·84 km.
	Bidston,	,,	43 m.,	,,	72°,	,,	3·02 km.
	Edinburgh,	,,	43 m.,	,,	71°,	,,	3·05 km.
	San Fernando,	,,	56 m.,	,,	90°,	,,	2·97 km.
	Christchurch	,,	81 m.,	,,	97°,	,,	2·21 km.
				Average .	.	.	2·79 km.

Earthquake No. 884, August 24, 1904, origin 135° E. 32° N.

East-West	Beirut,	time to travel	55 m.,	distance	79°,	velocity	2·65 km.
	Calcutta,	,,	25 m.,	,,	42°,	,,	3·09 km.
	Kodaikanal,	,,	44 m.,	,,	57°,	,,	2·39 km.
	Cape Town	,,	85 m.,	,,	129°,	,,	2·80 km.
				Average .	.	.	2·73 km.

North-South	Shide,	time to travel	60 m.,	distance	88°,	velocity	2·71 km.
	Kew,	,,	59 m.,	,,	86°,	,,	2·72 km.
	Bidston	,,	58 m.,	,,	85°,	,,	2·75 km.
	Edinburgh	,,	59 m.,	,,	84°,	,,	2·71 km.
	Toronto	,,	72 m.,	,,	98°,	,,	2·51 km.
	Christchurch	,,	40 m.,	,,	84°,	,,	2·88 km.
	Wellington	,,	44 m.,	,,	82°,	,,	3·51 km.
				Average .	.		2·82 km.

Earthquake No. 1111, January 21, 1906, origin 143° E. 34° N.

East-West	Calcutta,	time to travel	23 m.,	distance	49°,	velocity	3·94 km.
	Honolulu	,,	38 m.,	,,	51°,	,,	2·48 km.
				Average .	.	.	3·20 km.

North-South	Baltimore,	time to travel	72 m.,	distance	98°,	velocity	2·51 km.
	Kew,	,,	53 m.,	,,	89°,	,,	3·10 km.
	Bidston,	,,	56 m.,	,,	88°,	,,	2·90 km.
	Perth,	,,	37 m.,	,,	71°,	,,	3·55 km.
				Average .	.	.	3·01 km.

Earthquake No. 1170, April 18, 1906, origin 121° W. 38° N.

					Per sec.
East-West	Cape Town,	time to travel 83 m.,	distance 148°,	velocity	3·29 km.
	Toronto	" 21 m.,	" 33°,	"	2·90 km.
	Batavia,	" 91 m.,	" 125°,	"	2·54 km.
	Perth,	" 74 m.,	" 132°,	"	3·30 km.
	Honolulu,	" 17 m.,	" 34°,	"	3·70 km.
	Samoa,	" 33 m.,	" 69°,	"	3·86 km.
	Manila,	" 56 m.,	" 100°,	"	3·30 km.
			Average . . .		3.27 km.

North-South	Victoria,	time to travel 5 m.,	distance 10.5°,	velocity	3·86 km.
	Mauritius,	" 98 m.,	" 158°,	"	2·98 km.
	Calcutta,	" 68 m.,	" 112°,	"	3·04 km.
	Bombay	" 82 m.,	" 121°,	"	2·73 km.
	Kodaikanal,	" 74 m.,	" 127°,	"	3·17 km.
	Irkutsk,	" 53 m.,	" 80°,	"	2·78 km.
	Cairo,	" 82 m.,	" 107°,	"	2·41 km.
			Average . . .		2·95 km.

Earthquake No. 1260, September 7, 1906, origin 145° E. 35° N. (calculated by Mr. J. Horikawa).

East-West	Bombay,	time to travel 46 m.,	distance 65°,	velocity	2·61 km.
	Calcutta,	" 34 m.,	" 50°,	"	2·73 km.
	Kodaikanal,	" 44 m.,	" 65°,	"	2·72 km.
	Cape Town,	" 86 m.,	" 137°,	"	2·94 km.
	Mauritius,	" 67 m.,	" 100°,	"	2·78 km.
			Average . . .		2·74 km.

North-South	Shide,	time to travel 60 m.,	distance 92°,	velocity	2·64 km.
	Kew,	" 56 m.,	" 88°,	"	2·9 km.
	Bidston,	" 54 m.,	" 86°,	"	2·94 km.
	Edinburgh,	" 58 m.,	" 85°,	"	2·71 km.
	Paisley,	" 62 m.,	" 86°,	"	2·56 km.
	Perth,	" 59 m.,	" 72°,	"	2·25 km.
	Wellington,	" 63 m.,	" 82°,	"	2·40 km.
			Average . . .		2·62 km.

Earthquake No. 1363, April 18, 1907, origin 123° E. 13° N.

East West	Bombay,	time to travel 31 m.,	distance 48°,	velocity	2·43 km.
	Kodaikanal,	" 32 m.,	" 45°,	"	2·60 km.
	Samoa,	" 32 m.,	" 70°,	"	4·04 km.
	Honolulu,	" 45 m.,	" 75°,	"	3·08 km.
			Average . . .		3·04 km.

North-South	Shide,	time to travel 64 m.,	distance 101°,	velocity	2·91 km.
	Kew,	" 71 m.,	" 100°,	"	2·60 km.
	Edinburgh,	" 64 m.,	" 99°,	"	2·86 km.
	Paisley,	" 63 m.,	" 100°,	"	2·93 km.
	Tokio,	" 13 m.,	" 27°,	"	3·84 km.
	Perth,	" 33 m.,	" 46°,	"	2·57 km.
	Christchurch,	" 43 m.,	" 73°,	"	3·14 km.
			Average . . .		2·98 km.

Earthquake No. 1362, April 18, 1907, origin 124° E. 13° N.

						Per sec.
East-West	Bombay,	time to travel	31 m.,	distance 49°,	velocity	2·92 km.
	Kodaikanal,	,,	40 m.,	,, 45°,	,,	2·08 km.
	Honolulu,	,,	43 m.,	,, 74°,	,,	3·19 km.
				Average .	. .	2·73 km.

North-South	Irkutsk,	time to travel	28 m.,	distance 42°,	velocity	2·77 km.
	Shide,	,,	65 m.,	,, 102°,	,,	2·90 km.
	Kew,	,,	65 m.,	,, 102°,	,,	2·90 km.
	Bidston,	,,	54 m.,	,, 99°,	,,	3·39 km.
	Edinburgh,	,,	59 m.,	,, 99°,	,,	3·07 km.
	Tokio,	,,	14 m.,	,, 27°,	,,	3·56 km.
				Average .	. .	3·09 km.

Earthquake No. 1632, October 13, 1908, origin 102° W. 18° N.

East-West	Honolulu,	time to travel	28 m.,	distance 52°,	velocity	3·43 km.

North-South	Victoria,	time to travel	23 m.,	distance 35°,	velocity	2·81 km.
	Irkutsk,	,,	60 m.,	,, 105°,	,,	3·23 km.
	Tashkend,	,,	60 m.,	,, 122°,	,,	3·76 km.
	Victoria,	,,	23 m.,	,, 35°,	,,	2·81 km.
	Beirut,	,,	82 m.,	,, 114°,	,,	2·56 km.
	Edinburgh,	,,	54 m.,	,, 81°,	,,	2·77 km.
	Bidston,	,,	54 m.,	,, 79°,	,,	2·70 km.
				Average .	. .	2·95 km.

When we look at the averages at the end of the above nine tables, it appears that in seven instances the velocity for East-West motion has been greater than that given for North-South motion. In two instances—viz., those for Earthquakes Nos. 884 and 1362—the reverse has been the case.

If we combine the results for all nine earthquakes we get 35 observations for East-West motion, which give an average velocity of 2·96 km. per second, and 58 observations for North-South motion, the average velocity for which is 2·88 km. per second.

VI. *Comparison of the Amplitudes of East-West and North-South Motion at a given Station.*

At Eskdalemuir during the year 1910 two Milne pendulums, one of which recorded North-South motion and the other East-West motion, had periods which did not differ from each other more than one second. At times they had the same period, but usually the former had a period of 17 seconds and the latter 18 seconds. From this we should expect that, if the displacement of the booms was due to tilting, the amount of this as measured in millimetres would be slightly greater in the East-West direction than in the North-South direction. For 40 earthquakes recorded during this year this was the case, but there are 16 instances in which the boom recording North-South motion showed the greatest displacement. In nine instances the amount of displacement was the same on both pendulums. It may be added that for a short period—viz., from January 1 to February 12—the

boom recording North-South motion was as sensitive or more sensitive than the one recording East-West motion. Notwithstanding this, the amplitudes for East-West motion were usually greater than those for the North-South motion.

If, instead of comparing boom displacements measured in millimetres, we convert these into angular units, the conclusion arrived at is that East-West tilting is usually greater than that at right angles.

VII. *On the Direction in which Earthquake Motion is most easily propagated.*

In the British Association Report for 1908, p. 74, I discussed the direction in which megaseismic motion is most freely radiated. Two general conclusions at which I arrived were, first, that the motion of large earthquakes travelled farther westwards than it did eastwards, and, second, that the range of motion across the equator was shorter than it is to the East or West.

In the following note this inquiry has been extended to four groups of earthquakes, the members of each group having origins in the same district. Each earthquake is designated by a number corresponding to entries in the Shide Register, in the Circulars issued by the British Association, and also in a Catalogue published in the Report for 1912, p. 71.

District No. 1.—West Coast of Central America, or approximately 90° W. 5° N.

The earthquakes considered are Nos. 806, 1164, and 1450. As there are only three members in this group no single station can have more than three records.

At 11 stations lying northwards from this origin 25 records were made, or on the average 2·2 records per station. At five stations lying to the south of the origin eight records were obtained, the average therefore being 1·6 per station.

Inasmuch as all stations within 60 degrees of the origin each obtained the possible three records, I find that if these are omitted when comparing records obtained in the North with those obtained in the South I get the following results:—

Nine northerly stations recorded on the average two shocks Four southern stations recorded on the average 1·5 shocks.

I also find that the average distance from the origin of the 11 North-lying stations is 98 degrees, whilst that of the five southerly stations is 77 degrees.

From these examinations it would appear that for the three earthquakes considered, two of which were recorded at Batavia, 159 degrees distant from the origin, that motion was transmitted more freely towards the North than in the opposite direction.

If we compare the transmission of motion eastwards with that which is transmitted towards the West we obtain the following:—

At 11 eastern stations 19 records were obtained, or an average of 1·8 per station.

At eight western stations 17 records were obtained, or an average of 2·1 per station.

If we omit the stations lying within 60 degrees of the origin, the above two averages respectively become 1·5 and 2·0.

The average distance from the origin of the eastern stations is 88 degrees, whilst that of the western stations is 90 degrees—two distances which are practically equal.

The inference is that motion is transmitted more freely towards the West than it is towards the East.

District No. 2.—North of India, or approximately 80° E. and 40° N.

The earthquakes considered are Nos. 832, 886, 982, 1070, 1293, and 1468.

The number of records obtained at 9 stations lying to the North of this district was 46; the average per station was therefore 5.1.

At 8 stations lying to the South of this district 29 records were obtained, the average per station therefore being 3·6.

If we only consider stations more than 60 degrees distant from the origin, these two averages respectively become 5·2 and 3·8. Here, again, we are led to the conclusion that motion was propagated more freely towards the North than in the opposite direction.

It must, however, be pointed out that the average distance of these southern stations from the origins was somewhat greater than that of the northern stations, these distances being respectively 65 and 85 degrees.

To the East of long. 80° E. 33 records were obtained at 9 stations, or 3·6 records per station. To the West of this meridian 38 records were obtained at 9 stations, or on the average 4·2 records per station. It would seem, therefore, that in this district, as in District No. 1, motion was propagated more freely towards the West.

The average distances from the origin of these East and West stations are respectively 76 and 75 degrees.

District No. 3.—East Coast of Japan, or approximately 140° E. 40° N.

The earthquakes considered are Nos. 884, 1031, 1266, 1427, and 1510.

Nine stations with northerly bearings recorded 28 disturbances, or on the average 3·1 per station.

Eight stations with southerly bearings noted 20 disturbances, or on the average 2·5 per station.

If we only consider stations more than 60 degrees .distant from this district these averages become 3·0 and 2·6.

The average distance from the origin for the southerly stations is, however, somewhat greater than for the northerly stations, these distances respectively being 91 and 77 degrees.

Five stations lying to the East of 150° E. long. gave 13 records, or an average of 2·6 per station.

Eleven stations lying to the West of this same region yielded 34 records, or on an average 3·1 per station. Here again we observe motion has been propagated more freely towards the West.

District No. 4.—North and North-East of New Guinea, or approximately 150° E. and 0° N. or S.

The earthquakes considered are Nos. 977, 1025, 1128, 1190, 1272, 1301, and 1460.

Eleven stations North of the Equator recorded 61 disturbances, or an average of 5·5 per station. Six stations South of the Equator recorded 29 disturbances, or an average of 4·8 per station. If we only consider stations more than 60 degrees distant from an origin these averages respectively become 5·4 and 5.

That the average number of northern records preponderates over those obtained in the South seems more remarkable when we consider the average distances of these two groups of stations from the origin—the former being 95 degrees and the latter 75 degrees.

Six stations lying to the East of long. 150° E. noted 32 disturbances, or on the average 5·3 per station.

Twelve stations lying to the West of this meridian noted 65 disturbances, or an average of 5·4 per station.

This last result suggests that the quantity of motion propagated eastwards is the same as that which is propagated towards the West.

With this exception, the four groups of earthquakes considered indicate that motion travels to greater distances northwards and westwards than it does southwards and eastwards.

If we take the four districts together we find the following:—

40 northerly	stations gave	160 records,	or	4·0	per station.
27 southerly	,,	86	,,	3·2	,,
40 westerly	,,	154	,,	3·7	,,
31 easterly	,,	97	,,	3·1	,,

District No. 5.—West of South America, or approximately 80° W. 30° S.

The earthquakes considered are Nos. 1248, 1248B, 1277, 1398, 1851, and 1852.

Each of these six disturbances was recorded at two or more stations in Great Britain, 105 degrees distant from the origin.

Five were noted at San Fernando, Honolulu, and Cape Town, the respective distances of which from the origin are 95, 88, and 78 degrees. The average distance is 87 degrees.

Four were recorded at Toronto, Victoria, Azores, Tokio, Perth, and Zikaiwei. The distances of these from the origin are respectively 73, 83, 85, 145, 115, and 160 degrees. The average distance is 110 degrees.

Three were noted at New Zealand, Mauritius, Bombay, and Calcutta. The distances of these places are respectively 85, 125, 155, and 170 degrees. The average distance is 134 degrees.

Two were noted at Colombo, Kodaikanal, and Irkutsk, the distances of which are 150, 150, and 160 degrees; the average distance is 153 degrees.

One was noted at Sydney, 100 degrees distant.

This examination simply shows that stations near to an origin obtain more records than those at a great distance.

The average number of records for stations lying westwards from the origin is 3·4, and the average distance of these stations from the origin was 105 degrees. The average number of records for stations

lying eastwards from the origin was 4·6, and the average distance of these stations was 102 degrees.

The average number of records for stations lying northwards from the origin was 4·6, and the average distance of these stations was 101 degrees.

The average number of records for stations lying southwards from the origin was 3·2, and the average distance of these stations was 95 degrees.

Although the average distance of stations was practically the same, the greater number of records had been obtained at stations lying eastwards and northwards from the origin.

District No. 6.—Near New Zealand, or approximately 180° East or West, 40° South.

The earthquakes considered are Nos. 804, 877, 922B, and 1768.

Each of these four disturbances was recorded in New Zealand, and at approximately 180 degrees distance in Great Britain.

Three were recorded in Toronto, Perth, Honolulu, San Fernando, and India. The distances of these stations from the origin are 122, 52, 65, 180, and 105 degrees; the average distance is 105 degrees.

Two were noted at Victoria, B.C., Cape Town, Irkutsk, Mauritius, Cordova, and Batavia. The distances of these places from the origin are 102, 105, 112, 100, 85, and 72 degrees. The average distance is 96 degrees.

Only one disturbance was noted at Cairo and Sydney, the distances of which from the origin are respectively 150 and 22 degrees.

Ten stations with a northerly bearing recorded on the average 2·4 shocks, the average distance of these stations from the origin being 109 degrees.

Cape Town, which has a southerly bearing from the origin, recorded two shocks; its distance from the origin is 105 degrees.

Material for comparing propagation in these two directions is evidently too scanty.

Three stations to the eastward of the origin recorded on the average 2·3 shocks, the average distance being 103 degrees.

Six stations to the westward of the origin recorded 2·1 shocks, the average distance being 76 degrees.

The result of these examinations does not suggest that earthquake motion is radiated more freely in one particular direction rather than in some other.

For the six groups of earthquakes originating in six different districts it appears that more motion has been propagated towards the North than towards the South. For the first four groups more records were obtained to the westward of an origin than were obtained to the East of the same. For Groups 5 and 6 this is reversed, but it is based on observations which were comparatively few in number.

VIII. *On the Times of Occurrence of Maximum Motion on Pendulums Differently Oriented.*

In the records from certain stations (see British Association Circulars) we observe that the maximum for East-West motion is frequently reached from one to four or even more minutes before that for North-

South motion. A good illustration of this is found in all the registers from Eskdalemuir. In 1910 the East-West and North-South pendulums indicated a maximum 12 times simultaneously; the East-West pendulums, however, had a maximum 41 times in advance of and six times later than the North-South instrument. When the natural period of the pendulums was not identical they did not vary from each other more than one second, the period for the East-West recording instrument being 18 seconds whilst that for the North-South was 17 seconds. This slight difference in sensibility in the two instruments does not, however, explain why the East-West component, although usually giving earlier records, should occasionally give them simultaneously with and sometimes after the North-South instrument.

At San Fernando in South Spain there is a pair of Milne pendulums mounted to record East-West and North-South motion. The natural period of the first of these instruments is 16 secs., and 1 mm. deflection of the outer end of the boom corresponds to a tilt of $0''\cdot43$. The period of the second is 20 seconds, and 1 mm. deflection of the outer end of the boom is equivalent to a tilt of $0''\cdot25$. As regards the displacement produced by tilting, the first of these instruments, which records East-West motion, has only half the sensitiveness of the other. Notwithstanding this, in 1910 the maximum for East-West motion was obtained before North-South motion 17 times. Twice both pendulums recorded maxima simultaneously, while the very sensitive North-South instrument showed maxima 26 times earlier than the East-West boom.

IX. *Disturbances only recorded at Two or Three Widely Separated Stations.*

In the British Association Report for 1858, p. 55, Mallet refers to a number of shocks which had been felt simultaneously, or nearly so, at two distant places. The most remarkable pair are shocks noted at Okhotsk and Quito, places which are nearly antipodal to each other. As these coincidences cannot be assured within several hours, Mallet agrees with Mylne[1] that 'the probability of anything more than mere coincidence is extremely slight.'

In the British Association Reports, 1908, p. 64, and 1909, p. 51, I called attention to 148 small disturbances which had been noted in Jamaica. Fifty-one of these were undoubtedly recorded 43 minutes later at several stations in Great Britain. They were not, however, noted in Europe. This absence of records across the Channel was attributed to a want of sensibility in the seismographs which were there employed. Although we know that the seismograph recording photographically will pick up very small movements which may or may not be visible on the record received on smoked paper, whether a microseism shall or shall not be noted apparently depends not only on the sensibility of the recording instrument but on other conditions not yet defined.

As illustrative of this I called attention to the fact that from time to time Batavia and Cairo have recorded the same earthquake, which, however, has not been recorded at stations lying between

[1] See 'Brit. Earthquakes,' *Edin. Phil. Journ.*, vol. 31.

these places or at any other station in the world. The distance between these places is 80 degrees, and the times taken for compressional, distortional, and surface waves, or P_1, P_2 and P_3, to travel this distance would be 15, 24, and 50 minutes. A disturbance originating in Java might after one of these intervals be recorded in Cairo or it might in the vicinity of Cairo bring into existence a secondary disturbance. There would be practically the same time intervals between the observations at these two places if the primary disturbance had its origin somewhat to the East of Java. Had the origin of the primary been between Batavia and Cairo the time intervals might be anything less than the given three intervals. If the time intervals exceed 50 minutes it is extremely likely that these two records refer to independent earthquakes.

The following are illustrations of records peculiar to Batavia and Cairo made in 1911:—

Feb. 4 at 7.8	in Batavia and	64 m.	later in Cairo.		
Feb. 8 at 4.0	„	„	„		
Feb. 9 at 18.40	„	42 m.	„		
Feb. 10 at 17.25	„	42 m.	„		
Feb. 11 at 0.54	„	32 m.	„	.	Felt in Sumatra.
March 6 at 9.57	„	11 m.	earlier in Cairo.		
March 19 at 0.59	„	41 m.	later in Cairo.		
April 26 at 10.0	„	16 m.	„		
Aug. 2 at 10.7	„	22 m.	„		
Aug. 19 at 0.49	„	12 m.	„	.	Felt in Sumbawa.
Sept. 14 at 23.16	in Samoa and	19 m.	later in Cairo.		

The fact that with but one exception all these disturbances were recorded at Batavia before they were recorded at Cairo suggests that their origins were nearer to the former place than the latter.

Well-equipped stations nearer to Batavia than Cairo, and at which we should have expected to find records of these earthquakes, are the following: Mauritius, Tokio, Irkutsk, Zikawei, Tsing-tau, Calcutta, Bombay, Kodaikanal, Manila, Perth, Sydney, Wellington, Christchurch, Tiflis, Beirut, Harpoot, and Tashkend.

X. *Recurrence of Megaseismic Groups.*

Between 1899 and 1909 I find 88 groups of megaseisms. The number of disturbances in a group varies from 2 to 14, while the number of days over which a group extends varies between 1 and 25. The former numbers divided by the latter give what I call the seismicity of a group period. If three earthquakes have taken place on one day I call the seismicity 3, but if four have happened in 5 days I call it ·8. These seismicities, or earthquake-activity numbers, vary between ·4 and 3. In the following lines I give in the form of numerators and denominators the relationship between seismicities and the average number of days of rest which have followed each group.

$\frac{\cdot 4}{15}$ $\frac{\cdot 5}{10}$ $\frac{\cdot 6}{16}$ $\frac{\cdot 7}{8}$ $\frac{\cdot 8}{11}$ $\frac{\cdot 9}{7}$ $\frac{1\cdot 0}{8}$ $\frac{1\cdot 2}{9}$ $\frac{1\cdot 3}{8}$ $\frac{1\cdot 5}{8}$ $\frac{1\cdot 6}{11}$ $\frac{2\cdot 0}{8}$ $\frac{2\cdot 5}{10}$ $\frac{3\cdot 0}{6}$

No definite conclusion can be drawn from these figures, but in connection with them I must call attention to a somewhat similar investigation referred to in the Report for 1910, p. 54, where it is

shown that great megaseismic activity is followed by long periods of rest. In that case the intensity of a group was considered independently of the number of days over which it was spread.

XI. *Frequency of Earthquake Followers.*

In the British Association Reports, 1899, p. 227, and 1900, p. 71, under the title of 'Earthquake Echoes,' I discussed the vibrations which follow the main shock or shocks of an earthquake and which bring the same to a conclusion. These occur in groups, and as these rise and fall in amplitude it may be inferred that an earthquake does not become extinguished at a uniform rate, but it dies in surges. I sought for the origin of these surgings, particularly for those groups which resemble each other in form, in the hypothesis of repeated reflection.

Another possible explanation is to assume that these repetitions are interference phenomena consequent on the difference in period between the free swing of the recording pendulum and that of the earth.

Now steady-point seismographs have shown for earthquakes we can feel that their period increases as they die out at a given station, and that it also increases as they radiate from an origin. Assuming this to be correct for megaseismic motion, then beats or recurrences at stations at different distances from an origin should show differences in their frequency. To test this I have compared the time frequency of pulsatory recurrences for disturbances recorded in the Isle of Wight which originated in different localities.

The localities chosen were as follow:—

1. East Coast of Japan, distant from Shide . . . 80° to 85°.
2. West Coast Central America, distant from Shide . 80° to 85°.
3. Central Asia, distant from Shide . . . . 50° to 60°.
4. Between East New Guinea and Fiji, distant from Shide 130° to 140°.

The earthquakes originating in these four districts, and of which I have seismograms recorded in the Isle of Wight, are referred to by numbers corresponding to the numbers given in the Earthquake Catalogue published in the British Association Reports, 1911, p. 5., and 1912, p. 71.

For *District No.* 1 these numbers were 263, 397, 405, 425, 431, 446, 448, 450, 457, 483, 493, 514, 884, 1031, 1266, 1427, and 1510. The average time interval between successive groups was found to be 2·8 minutes.

For *District No.* 2 the numbers were 248, 264, 407, 415, 417, 432, 447, 536, 576, 606*a*, 642, 806, 924*b*, 1164, 1450. The average time interval for these disturbances was 3·4 minutes.

For *District No.* 3 the numbers were 542, 558, 626, 644, 662, 663, 832, 886, 982, 1064, 1070, 1293, 1468. The average time interval for these disturbances was 2·7 minutes.

For *District No.* 4 the numbers were 351, 352, 354, 377, 435, 515, 530, 581, 977, 1025, 1128, 1190, 1272, 1301, and 1460. The average time interval for these disturbances was 2·8 minutes.

If we compare the time intervals for Districts 1, 3, and 4, it would

appear that these are not dependent on the distance at which they are recorded from an origin.

XII. *Large Earthquakes recorded at different Observatories, January to June* 1910.

The total number of large earthquakes, each of which disturbs a continental area, between January and June 1910, was about 166. Each of these was recorded at from 3 to 50 or 60 different observatories, and all extended to a distance of more than 20 degrees from their origin. In the following tables, drawn up by the late Shinobu Hirota, instruments which record photographically are followed by the letter P, whilst those which write mechanically on a smoked surface are marked S. The Milne instruments, unless otherwise stated, are single-boom instruments recording East and West motion only.

DISTRICT I.—*British Islands, Central and Western Europe.*

Station	Foundation	Seismographs	Instrument	No. of Cor. Records
Shide	Disintegrated Chalk	Milne, twin boom	P.	144
Hamburg	Alluvium	Wiechert, Hecker	P. & S.	131
Edinburgh	Andesite Lava	Milne	P.	111
Bidston	New Red Sandstone	Milne	P.	75
Strassburg	Thick Compact Gravel	Wiechert, Rebeur-Ehlert, Milne, Vicentini, Schmidt, Mainka	P. & S.	68
Göttingen		Wiechert	P. & S.	64
Vienna	Alluvium	Wiechert	S.	64
Paris		Wiechert, Bosch-Mainka	S.	59
Kew	Thick Alluvium	Milne	P.	58
San Fernando	Calcareous Rock	Milne, two machines	P.	56
W. Bromwich	Thick Alluvium	Milne	S.	55
Grenada	Limestone	Stiatesi, Wiechert, Vicentini and Omori	S.	50
Laibach	Alluvium	Vicentini, Grablovitz-Belar, Rebeur-Ehlert	P. & S.	43
Eskdalemuir	Palæozoic Rock	Milne, twin boom	P.	27
Catania	Rock	Cancani, Vicentini, Agamennone, Omori	S.	26
Malta	Limestone	Milne	P.	26
Azores	Basalt	Milne	P.	23
Tortosa	Alluvium	Vicentini, Grablovitz	S.	22
Monte Cassino	Limestone	Cancani	S.	17

DISTRICT II.—*North America.*

Station	Foundation	Seismographs	Instrument	No. of Cor. Records
Victoria, B.C.	Hard Pan above Igneous Rock	Milne	P	36
Toronto	Alluvium	Milne	P.	35
Ottawa	Boulder Clay	Bosch	P.	34
St. Louis, U.S.A.	Alluvium	Wiechert	S.	13

District III.—*W. Pacific, Australia, and New Zealand.*

Station	Foundation	Seismographs	Instrument	No. of Cor. Records
Cairo . .	Eocene Limestone .	Milne, two instruments	P.	91
Tiflis . .	Rock	Milne, Rebeur-Ehlert, Bosch, Zollner and Cancani	P. & S.	85
Adelaide .	Thick Alluvium .	Milne	P.	76
Batavia .	Alluvium . . .	Milne, Rebeur-Ehlert, Wiechert	P. & S.	67
Zikawei . .	Thick Alluvium .	Omori, Wiechert .	S.	53
Osaka . .	Thick Alluvium .	Omori	S.	52
Honolulu .	Coral Limestone .	Milne	P.	52
Riverview, Sydney	Sandstone . .	Wiechert . . .	S.	51
Manila . .	Alluvium . . .	Gray-Milne, Bertelli, Cecchi, Vicentini, Omori	P. & S.	48
Sydney . .	Clay and Ironstone Shale	Milne	P.	45
Tsintau .		Wiechert . .	S.	45
Mauritius .	Alluvium on Basalt	Milne	P.	38
Kodaikanal .	Rock	Milne	P.	37
Calcutta .	Alluvium . . .	Milne	P.	31
Wellington, N.Z.		Milne	P.	34
Colombo .	Laterite . . .	Milne	P.	27
Mizusawa .	Alluvium . . .	Omori	S.	24
Bombay .	Red Earth above Basalt	Milne, Colaba, Omori	P. & S.	22
Tokio . .	Alluvium . . .	Milne	P.	21
Perth, West Australia	Limestone . .	Milne	P.	15
Reykjavick .	Volcanic Materials .	Wiechert . . .	S.	16

A glance at the preceding tables shows that while one station has recorded 144 of the possible 166 disturbances, another station has only recorded 15. These marked differences in the number of records in different places are dependent upon many conditions, and at no two stations are the conditions exactly the same. At one, rapid changes in temperature may be accompanied by air tremors, which may eclipse all but the largest seismic records. In this respect I have found marked differences between adjoining rooms. At certain observatories insects, particularly small spiders, cause trouble. A more important cause leading to differences in the number of earthquakes recorded at stations in the same district is difference in the adjustment of the instrument. If two horizontal pendulums have different periods, the one with the longer period yields the greater number of records. Unfortunately, however, it is the one most influenced by air tremors. The expiring efforts of large earthquakes, which at a distance from their origin may be represented by minute ripples or thickenings in consequence of their smallness, have frequently been overlooked. Proximity to or remoteness from epicentral district has naturally a considerable influence upon the number of records obtained at a station.

Those stations which are in or near to areas in which large earthquakes radiate, as, for example, Batavia, Manila, and Osaka, should obtain more records than Toronto, Ottawa, and St. Louis, which are distant from sites of seismic activity. For this reason stations have been grouped according to their relative distances from seismic regions. The first group refers to stations in the British Isles, Central and Western Europe, the second group is in North America, and the third group is India, the Western side of the Pacific, Australia, and New Zealand.

The average number of records obtained in these three districts is respectively 58, 29, and 41, but why the average for the first of these districts should exceed that for the last is contrary to expectations, and to explain it we must look for something more than nearness to or distance from epicentral regions.

If we consider the average number of records given by different types of instruments in different districts, the results we arrive at are as follow:—

In District	1	the average number of	photographic	records was	69
"	1	"	smoked-paper	"	55
"	2	"	photographic	"	35
"	2	"	smoked-paper	"	13
"	3	"	photographic	"	39
"	3	"	smoked-paper	"	45

Districts 1 and 2, together with records from Cairo, Tiflis, and Reykjavick, indicate that with photographic recording apparatus more records can be obtained than with mechanical registration. The same is true if we take all the records, including those for District 3, *en bloc*, but for this latter district by itself the conclusion is reversed.

If we next turn to the character of the foundations we find for Districts 1 and 3 that the average number of records obtained if this was rock was 52, but where it was alluvium it was 50.

Other observations bearing upon this subject will be found in British Association Reports for 1901, pp. 43 and 51; 1902, p. 68; 1903, p. 81; and 1904, p. 42.

XIII. *Seismic and Volcanic Activities.*

In the Report for 1912, p. 102, I pointed out the material in certain catalogues suggested that volcanic and seismic activities in the world increased and decreased independently of each other. From this it might be inferred that if there is any periodicity in volcanic activity it would not be the same as the one exhibited by the megaseisms. With the object of examining this question more closely I asked Mr. Leo Kelley, of Dublin, who has made an extensive collection of materials in connection with volcanoes, to furnish me with a list of eruptions which have taken place during the last 200 years. This he kindly did, but unfortunately in many instances the authors from whom he has quoted only mention the year in which an eruption took place and omit the month and date. In the first

column of the accompanying table the year is given, and in the second and third columns the number of eruptions and earthquakes. The earthquake numbers are taken from the 'Catalogue of Destructive Earthquakes,' published in the Report for 1911. In this table we have entries relating to 110 years. When we compare successive years we see, for example, that in 1790 there were 14 eruptions and 11 earthquakes, but in the year following the number of eruptions had fallen to seven, while the number of earthquakes remained constant—volcanic activity had decreased while seismic activity suffered no change.

Year	No. of Eruptions	No. of Earthquakes	Year	No. of Eruptions	No. of Earthquakes	Year	No. of Eruptions	No. of Earthquakes
1790	14	11	1827	20	16	1864	10	33
1791	7	11	1828	21	23	1865	10	24
1792	7	7	1829	10	15	1866	5	28
1793	12	5	1830	15	18	1867	9	32
1794	5	11	1831	10	14	1868	15	41
1795	5	4	1832	9	7	1869	21	41
1796	10	6	1833	8	9	1870	12	28
1797	11	4	1834	10	11	1871	16	33
1798	5	6	1835	12	11	1872	24	30
1799	8	9	1836	16	11	1873	5	38
1800	5	6	1837	7	9	1874	9	32
1801	5	6	1838	18	7	1875	12	31
1802	5	11	1839	8	16	1876	9	20
1803	7	6	1840	10	11	1877	22	21
1804	6	4	1841	9	23	1878	24	32
1805	7	6	1842	8	7	1879	11	25
1806	10	15	1843	18	15	1880	8	35
1807	6	3	1844	11	14	1881	5	45
1808	6	7	1845	14	21	1882	5	27
1809	4	10	1846	12	26	1883	29	27
1810	3	8	1847	19	29	1884	7	33
1811	7	8	1848	14	20	1885	18	57
1812	11	18	1849	12	17	1886	18	29
1813	2	6	1850	11	14	1887	8	34
1814	7	10	1851	10	30	1888	8	34
1815	7	10	1852	30	35	1889	7	33
1816	4	3	1853	11	35	1890	5	19
1817	7	5	1854	16	27	1891	5	20
1818	9	9	1855	17	36	1892	8	24
1819	8	12	1856	27	30	1893	17	30
1820	13	7	1857	20	32	1894	19	42
1821	9	12	1858	8	36	1895	5	20
1822	22	14	1859	10	24	1896	3	26
1823	12	7	1860	11	26	1897	3	35
1824	8	10	1861	8	35	1898	4	21
1825	17	9	1862	10	43	1899	8	18
1826	10	8	1863	8	34	1900	3	—

Prof. H. H. Turner writes to me about the above table as follows:—

'If we calculate the correlation between these annual totals as they stand, we obtain the coefficient

$$r = +0{\cdot}45 \pm 0{\cdot}05.$$

But there is a systematic effect which should first be eliminated. A

mere glance at the figures shows that the number of recorded earthquakes steadily increases; in the first 50 years (1790-1839) there are 471, and in the last 50 years (1850-1899) there are 1555. The number of eruptions also increases, though not so markedly: in the first 50 years there are 465, and in the last 50 years 601. Now it seems probable that these increases are chiefly due to increased facilities for newsgathering; at any rate, a real secular change of this kind would require independent evidence. Further, it is clear that if the two series of numbers are both steadily increasing there will be a tendency for small numbers in one series to be associated with small numbers in the other, and large with large—that is to say, we shall get a spurious correlation (or rather, a spurious increase in the correlation) due to this cause.

'Hence a further computation was undertaken in which the secular effects were eliminated in the following manner:—

'Taking 10 yearly sums, the numbers and their logs are:—

Years	No. of Eruptions	Log.	Calc.	O–C	No. of Earthquakes	Log	Calc.	O–C
1790–9 . .	84	1·92	1·71	+·21	74	1·87	1·67	+·20
1800–9 . .	61	1·78	1·84	–·06	74	1·87	1·81	+·06
1810–9 . .	65	1·81	1·94	–·13	89	1·95	1·95	·00
1820–9 . .	142	2·15	2·01	–·06	121	2·08	2·07	+·01
1830–9 . .	113	2·05	2·07	–·02	113	2·05	2·16	–·11
1840–9 . .	127	2·10	2·10	·00	183	2·26	2·26	·00
1850–9 . .	160	2·20	2·11	+·09	299	2·48	2·34	+·14
1860–9 . .	107	2·03	2·09	–·06	337	2·53	2·41	+·12
1870–9 . .	144	2·16	2·06	+·10	290	2·46	2·47	–·01
1880–9 . .	113	2·05	2·00	+·05	374	2·57	2·51	+·06
1890–9 . .	77	1·89	1·91	–·02	255	2·51	2·55	–·14

'The "calculated" columns are from the formulæ

$$\text{Eruptions} \quad 2{\cdot}10 + n \times 0{\cdot}020 - n^2 \times 0{\cdot}0114,$$
$$\text{Earthquakes} \quad 2{\cdot}26 + n \times 0{\cdot}087 - n^2 \times 0{\cdot}0060,$$

where n is the number of the term, counting from the middle term (1840-9). Part of these assumed secular terms may, of course, be real; but we have no means of testing the point, and for the present we shall assume that they are spurious and therefore to be eliminated.

'When these formulæ are suitably modified and applied to the individual years and the correlation again calculated it is found to be

$$r = 0{\cdot}39 \pm 0{\cdot}05.$$

This is still quite comparable with the former value, and the conclusion seems justifiable that earthquakes and eruptions are affected by the same cause.'

XIV. *Report on an Improved Seismograph.*

Experiments are being made by Mr. J. J. Shaw, of West Bromwich, with a view to increase the efficiency and economy of the Milne-type seismograph.

The improvements it is proposed to incorporate are electro-magnetic damping, more delicate means of calibrating, clearer definition in the trace of seismograms, a still further economic use of the sensitised paper, increased maximum amplitude, adjustable light slits, &c.

Hitherto these pendulums have been quite undamped (except for the natural damping of the mechanism), and herein has partly lain the secret of its very high degree of sensitivity. The fact has long been recognised that most forms of damping, such as the air and liquid systems used on the Continent, would be too crude to apply to so sensitive an apparatus.

The Galitzin method of electro-magnetic damping seemed to offer the best opportunities for development; but the lightness and delicacy of the Milne booms is such that the addition of heavy copper plates was impracticable. Tests have been made with aluminium foil, and it has been found that this metal is superior to copper for the purpose, in so far that its conductivity is higher than that of copper, weight for weight.

Partly due to the feeble inertia of these pendulums and partly to the efficiency of the aluminium as a damping medium, it is found that a strong magnetic field acting upon five grains of the metal will give a damping effect of 8:1. Any lower value is readily obtained by a sliding adjustment.

The new calibrating device will obviate the usual disturbance of the apparatus in the process, either by opening cover cases or walking round the pedestal. The usual calibrating screw is fitted with a worm and wheel; one whole turn of the worm produces a 2-degree turn of calibrating screw, which gives a tilt of $2''$ of arc.

The worm is operated from the vicinity of the clock-box by means of an intervening length of flexible cable, and the movement of the calibrating screw is read on a scale fixed on top of the recording case. The angular motion is read by means of a beam of light from a mirror fixed to the calibrating screw. This direct reading eliminates any error due to flexure in the cable or worm.

XV. *Indexing Materials published by the British Association and the Seismological Society of Japan relating to Geophysics.*

Although the British Association has since the year 1841 published fifty-three Annual Reports and other notices about seismology and other branches of geophysics, it is but rarely these are referred to by modern investigators. To make these publications better known and to give to geophysicists an easy means of reference to them, the following index has been compiled. With these a few references are made to the 'Transactions of the Seismological Society of Japan' and the 'Seismological Journal.' The former are indicated by the letters T.S. and the latter by S.J. These for the most part are detailed accounts of investigations which in the Reports of the British Association are only referred to as abstracts.

Authors' names are attached to all reports and writings, with the exception of those written by myself.

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XVI. *Shinobu Hirota.*

Many in the Isle of Wight, and many more outside, will regret to hear of the death of Shinobu Hirota, which sad event took place at his home in Japan on April 24. He came to England in 1895, and within a week of his arrival the seismograph which he brought with him was at work at Shide. To convince those who had doubts as to the possibility of recording an earthquake which had originated even so far away as our antipodes and to corroborate whatever records might be obtained at Shide, a second instrument was installed at Carisbrooke Castle. To look after this Hirota had, wet or fine, a daily walk of four miles. The fact that these two instruments gave similar records and also that from a single record we could tell the distance from which a megaseism had originated, naturally attracted some attention. Directly it was shown that certain sub-oceanic disturbances had interrupted cables, Colonies desirous of knowing the cause of these sudden isolations from the rest of the world set up seismographs. This was the commencement of the British Association co-operation of seismological stations. To bring this into being Hirota played an active part. He knew personally many of the directors, and gave instruction to their officers. In practical seismometry he made many innovations, some of which have rendered instruments more sensitive. His multiplying levers made of grass stems gathered from 'bents' give pointers exactly one-third the weight of their equivalent in aluminium and yet twice if not three times as stiff. It was by using these that we got at Bidston the first record of rock deformation due to tidal load. In the workshop he was a good all-round workman, and in the Observatory office he kept most careful records. For photographic work he held a gold medal from the Isle of Wight Photographic Society. Above all this, his sharp eyes would find in a seismogram two records where at other stations only one had been discovered.

In view of the great attention and large sums which have been spent, particularly in foreign countries, on the new seismological departure, I feel it my duty to give recognition to an assistant pioneer in these new studies. His work is embodied in annual Seismological Reports for the last seventeen years and twenty-six Circulars, being the records received from observatories. His chief work at Shide was to assist in working up an absolutely new branch of geophysics, which has received recognition throughout the world. He died at the age of forty-three.

XVII. *John Milne.*

The above Report was, as stated in the heading, drawn up by the Secretary of the Committee, and in correcting the proof alterations have been made as sparingly as possible.

It falls to the lot of the Chairman to add a paragraph recording the sudden removal of the mainstay of the work. John Milne died, with but a few days' warning, on July 31. This is not the time or place for an adequate account of his life and work; but it may fitly be recalled that since he became Secretary of this Committee in 1895, seismology

has become a new science, largely owing to his own initiative. During twenty years' residence in Japan he became acquainted with earthquakes as disasters, and devoted himself to the study of them at close quarters, with a view to preventing loss of life. On his return to England he looked for a place where these studies at close quarters might be continued on minor disturbances, and Shide was selected after consultation with Professor J. W. Judd, F.R.S., then Chairman of this Committee. But almost simultaneously the possibility of detecting large earthquakes at a distance was realised; at once Milne seized the new opportunity; he devised a simple instrument for collecting such distant records, and stimulated the establishment of stations equipped with this instrument scattered over the globe, especially in British territory. Their records were sent to him at Shide, and he gave them information in return which maintained their interest and enthusiasm. The results are embodied in the annual reports of this Committee, in which the growth of a new department of knowledge can be traced. Facts about the structure of our globe are now familiar which were not only unsuspected in themselves when Milne began work, but to which it was not suspected that we had the means of access. Milne was cordially recognised, at the last meeting of the International Seismological Association, as the pioneer in their discovery.

Such a man cannot be replaced. At a meeting of the Committee held on September 10, 1913, it was determined that the work he had organised should for the present be carried forward as nearly as possible on the same lines as before. Mr. J. H. Burgess, who has for some years past been assisting Professor Milne at Shide (especially since the departure of Shinobu Hirota for Japan last year), will carry on the routine, under the general direction of the Chairman of the Committee. Professor Perry has accepted nomination as Secretary of the Committee, as a purely temporary expedient, which will allow of full consideration of a successor. It will not be easy to raise funds for the proper continuation of the work, even on the present lines, since Professor Milne himself subsidised the work to an unknown amount; but this provision of funds is under consideration.

The following resolution was passed by the General Committee of the British Association on September 17:—

> 'That this Committee desires to put on record its deep sympathy with Mrs. Milne, and its profound sense of the loss which seismology, and especially British seismology, has sustained in the death of John Milne. As Secretary of the Committee from 1895 to his death, he secured the establishment of half a hundred observing stations scattered over the face of the earth; he organised a co-operative scheme of work among them and incorporated the results of it in a series of Reports of this Committee which have revolutionised the science, if indeed they may not rather be said to have created it.'

The further Tabulation of Bessel and other Functions.—Report of the Committee, consisting of Professor M. J. M. HILL (*Chairman*), Professor J. W. NICHOLSON (*Secretary*), Mr. J. R. AIREY, Professor L. N. G. FILON, Sir GEORGE GREENHILL, Professor ALFRED LODGE, *and* Professor A. G. WEBSTER.

[PLATES II., III., AND IV.]

THE grant of 30*l.* given to the Committee during the past year has been expended on the calculation of the Elliptic Function Tables, according to the scheme of Sir George Greenhill approved by the Association. The Tables of these functions, printed in the present report, are accompanied by some graphs, and by a further explanation prepared by Sir George Greenhill. One of these Tables is given only in a skeleton form in the present report.

The Committee desires reappointment, with a further grant of 30*l.* during the coming year. It is proposed that this should be expended mainly on the further calculation of the I, Y, and K Bessel Functions, as the Secretary has received several requests for such Tables from scientific workers during the past year. The remainder of the approved scheme of work on the Elliptic Function Tables does not require much expenditure for the present.

Mr. Airey has completed his Tables of the Neumann Functions or Bessel Functions of the second kind, for an argument $x=0{\cdot}00$ to $x=15{\cdot}26$, at intervals of 0·01. The functions are of order zero and unity, and the Tables can be made a basis for the accurate calculation of the functions of higher orders. The Committee desires to point out that this very complete and important Table is entirely the work of Mr. Airey, and has been calculated without a grant. The necessity of a grant for the continuation of this part of the work will be apparent.

The Committee seeks the formal sanction of the Association for a change of name to '*The Committee for the Calculation of Mathematical Tables.*' Its scope has been enlarged several times by the Association, and this change of name seems now to be necessary.

The Committee desires to recommend that, in view of the scarcity of the past reports, more copies should be printed, and at the same time a smaller number placed on the tables at the meeting, so that the greater number of those printed should be placed in the hands of the Secretary for distribution.

Part I. Elliptic Functions.

Report III. on Tables of the Elliptic Function.

Ten new tables have been calculated, for which the ratio of the periods

$$\frac{K}{K'}=\frac{1}{\sqrt{2}},\ \sqrt{2},\ 2\sqrt{2},\ 2\sqrt{3},\ 3,\ \frac{3}{\sqrt{2}},\ 3\sqrt{2},\ 3\sqrt{3},\ 4,\ 5.$$

The square root of a rational number was chosen as the period ratio, so as to utilise the singular modulus of the elliptic function which arises in the theory of Complex Multiplication, and thence obtain an independent numerical check.

The table of the period ratio $K'/K=\sqrt{3}$ and modular angle $\theta=15°$ has been printed already; also of $K/K'=\sqrt{3}$, $\theta=75°$; and thence the table for $K/K'=2\sqrt{3}$ or $3\sqrt{3}$ was derived by the quadric or cubic transformation.

The table for

$$K=4K',\ \kappa'=\left(\frac{\sqrt[4]{2}-1}{\sqrt[4]{2}+1}\right)^2,$$

was calculated by a quadric transformation of $K=2K'$, given in Report II., and it could have been calculated immediately from $K=K'$ by a quartic transformation; and $K=5K'$, $\sin 2\theta=(2\sin 18°)^{12}$ was calculated by a quintic transformation of $K=K'$.

A sketch of the table for

$$K=7K',\ \sin 2\theta=\left(\frac{\sqrt{7}+1-\sqrt{2}\sqrt[4]{7}}{2\sqrt{2}}\right)^{12},\ \sqrt[4]{\kappa}+\sqrt[4]{\kappa'}=\sqrt[8]{2},$$

is submitted, obtained from $K=K'$ by a transformation of the seventh order, with a view of showing the shape of the curve for E (r), D (r), A (r) in a penultimate form, when the modular angle is undistinguishable from a right angle.

Curves of the function E (r), D (r), A (r) are given in the figures to show the change of shape as the modular angle θ increases from 0° to 90°.

It will be observed that these curves are featureless for θ up to 15°, and even to 45°, showing that the elliptic function does not require tabulation for a modular angle much below 45°, as E(r), D(r), A(r) may be replaced by a circular function formula within the limits of accuracy of the four significant figures required in a practical problem.

But in the important cases which arise in physical applications of a modular angle in the last degree of the quadrant it will be noticed that the curve of a function preserves a definite character in a penultimate form, even when the modular angle is undistinguishable from a right angle, provided the period ratio is assigned.

The tabulation must be abandoned here which takes the modular angle as a parameter of the function; and the period ratio K/K', or else Jacobi's $q=\exp(-\pi K'/K)$, must be adopted instead, as the parameter of a table.

To ensure the accuracy of a transformation formula employed in the calculation of a table the check values were applied at the beginning and end, $r=0$ and 90; half-way, at bisection, where $r=45$; and then at tri-

section, $r=30$, 60; and at quinquesection, when possible, where $r=18$, 36, 54, 72; in accordance with the formulas of Report I., pages 6, 7, which provide an algebraical numerical value to contrast with the number obtained by the expansion of a q series, or else by the formula of transformation.

These check values can be assigned for a singular modulus, and are given as they arise in the calculation of a table, and entered at once on the sheet of numbers to serve as standard points of reference in the same way as the cyclotomic values in a table of the circular function.

Thus in all cases we have the check values—

$$E(0)=0, \qquad D(0)=1, \qquad A(0)=0,$$

$$E(90)=0, \qquad D(90)=\frac{1}{\sqrt{\kappa'}}, \qquad A(90)=1;$$

$$E(45)=\frac{1-\kappa'}{2},\ D(45)=\left(\frac{1+\kappa'}{2\kappa'^{\frac{1}{2}}}\right)^{\frac{1}{2}},\ A(45)=\left(\frac{\kappa'^{\frac{1}{2}}}{2+2\kappa'}\right)^{\frac{1}{2}},\ \tan\phi(45)=\frac{1}{\sqrt{\kappa'}}=D(90).$$

The trisection and quinquesection formulas are given on pages 6, 7, Report I., and at full length in the 'Phil. Trans.,' 1904, pages 261, 264; and they can be quoted as required in the check of a table.

Thus the new table for $K'/K=\sqrt{2}$, $\kappa=\sqrt{2}-1=\sin 24°\cdot 47$, required the q series formulas for a complete tabulation; and it was checked at trisection by taking $b=\sqrt{3}+\sqrt{2}$.

The table for $K/K'=\sqrt{2}$, $\kappa'=\sqrt{2}-1$, can be derived by the second quadric transformation, and checked at trisection by $b=\sqrt{3}-\sqrt{2}$.

Another quadric transformation gave $K/K'=2\sqrt{2}$, and here $b^2=(\sqrt{2}+1)(2+\sqrt{3})$ for trisection.

Any function, such as $A(r)$, may be distinguished as regards the period ratio by writing it

$$A\left(r, \frac{K}{K'}\right),$$

and the formulas of the second quadric transformation are written

$$A\left(r, 2\frac{K}{K'}\right)=A\left(r, \frac{K}{K'}\right) \cdot \frac{D\left(r, \frac{K}{K'}\right)}{D\left(90, \frac{K}{K'}\right)}$$

$$D\left(r, 2\frac{K}{K'}\right)= D\left(r, \frac{K}{K'}\right)^2+\frac{\kappa}{\kappa'} \cdot A\left(r, \frac{K}{K'}\right)^2$$

$$E\left(r, 2\frac{K}{K'}\right)=\frac{E\left(2r, \frac{K}{K'}\right)+\frac{\kappa}{\sqrt{\kappa'}} \cdot \frac{A\left(2r, \frac{K}{K'}\right)}{D\left(2r, \frac{K}{K'}\right)}}{1+\kappa}$$

So also for the second cubic transformation, requiring in going from K/K′ to 3K/K′, the formulas can be written, putting for simplicity A(r) for A(r, K/K′), . . . ,

$$A(r, 3K/K') = A(r)^3 \left[\frac{B(60, K'/K)^2}{D(60, K'/K)^2} + \frac{\kappa'}{\kappa}\frac{D(r)^2}{A(r)^2}\frac{A(60, K'/K)^2}{D(60, K'/K)^2}\right]$$

$$D(r, 3K/K') = D(r)^3 \left[1 + \frac{A(r)^2}{D(r)^2}\frac{A(60, K'/K)^2}{B(60, K'/K)^2}\right]$$

$$ME(r, 3K/K') = 3E(r) + 2\kappa \frac{A(r)\, B(r)\, C(r)\, \dfrac{A(60, K'/K)^2}{B(60, K'/K)^2}}{D(r, 3K/K')}$$

$$M = \frac{1 + \operatorname{cn} \frac{2}{3}K}{1 - \operatorname{cn} \frac{2}{3}K}.$$

In this way the table was obtained of

$$\frac{K}{K'} = 3, \frac{3}{\sqrt{2}}, 3\sqrt{2}, 3\sqrt{3}, \ldots \text{ from } \frac{K}{K'} = 1, 1, \frac{1}{\sqrt{2}}, \sqrt{2}, \sqrt{3}, \ldots$$

At the trisection check

$$M = b = \sqrt[4]{3}\,\frac{\sqrt{6} + \sqrt{2}}{2} = 2\sqrt[4]{3} \sin 75^\circ,\ 3(\sqrt{3} + \sqrt{2}),\ 3(\sqrt{3} - \sqrt{2}), \ldots$$

In deriving K = 5K′ from K = K′, the formulas of the quintic transformation were

$$A(r, 5) = A(r)^5 \left[\frac{B(36)^2}{D(36)^2} + \frac{D(r)^2}{A(r)^2}\frac{A(36)^2}{D(36)^2}\right]\left[\frac{B(72)}{D(72)} + \frac{D(r)^2}{A(r)^2}\frac{A(72)^2}{D(72)^2}\right]$$

$$D(r, 5) = D(r)^5 \left[1 + \frac{A(r)^2}{D(r)^2}\frac{A(36)^2}{B(36)^2}\right]\left[1 + \frac{A(r)^2}{D(r)^2}\frac{A(72)^2}{B(72)^2}\right]$$

$$ME(r, 5) = E(r) + 2E(2r) + \frac{A(2r)}{D(0)D(2r)}\left[\frac{\dfrac{A(r)^2}{D(r)^2} + \dfrac{A(36)^2}{B(36)^2}}{1 + \dfrac{A(r)^2}{D(r)^2}\dfrac{A(36)^2}{B(36)^2}} + \frac{\dfrac{A(r)^2}{D(r)^2} + \dfrac{A(72)^2}{B(72)^2}}{1 + \dfrac{A(r)^2}{D(r)^2}\dfrac{A(72)^2}{B(72)^2}}\right]$$

$$M = \frac{1 + \operatorname{cn} \frac{4}{5}K}{1 - \operatorname{cn} \frac{4}{5}K}\ \frac{1 + \operatorname{cn} \frac{8}{5}K}{1 - \operatorname{cn} \frac{8}{5}K} = \sqrt{5} - 2.$$

A quinquesection test can be applied here of the formulas on page 7, Report I., by taking

$$c-\frac{1}{c}=64\,(\sin 18^\circ)^5=2\left(\frac{\sqrt{5}-1}{2}\right)^5=5\sqrt{5}-11,$$

$$c+\frac{1}{c}=2\sqrt{5}\left(\frac{\sqrt{5}-1}{2}\right)^2\sqrt{\frac{5-\sqrt{5}}{2}}.$$

So also for $K=7K'$ from $K=K'$; the transformation formulas would be

$$\begin{aligned}\mathrm{A}(r,7)=\mathrm{A}(r)^7&\left[\frac{\mathrm{B}(\frac{180}{7})^2}{\mathrm{D}(\frac{180}{7})^2}+\frac{\mathrm{D}(r)^2}{\mathrm{A}(r)^2}\frac{\mathrm{A}(\frac{180}{7})^2}{\mathrm{D}(\frac{180}{7})^2}\right]\\&\left[\frac{\mathrm{B}(\frac{360}{7})^2}{\mathrm{D}(\frac{360}{7})^2}+\frac{\mathrm{D}(r)^2}{\mathrm{A}(r)^2}\frac{\mathrm{A}(\frac{360}{7})^2}{\mathrm{D}(\frac{360}{7})^2}\right]\\&\left[\frac{\mathrm{B}(\frac{540}{7})^2}{\mathrm{D}(\frac{540}{7})^2}+\frac{\mathrm{D}(r)^2}{\mathrm{A}(r)^2}\frac{\mathrm{A}(\frac{540}{7})^2}{\mathrm{D}(\frac{540}{7})^2}\right]\end{aligned}$$

$$\begin{aligned}\mathrm{D}(r,7)=\mathrm{D}(r)^7&\left[1+\frac{\mathrm{A}(r)^2}{\mathrm{D}(r)^2}\frac{\mathrm{A}(\frac{180}{7})^2}{\mathrm{B}(\frac{180}{7})^2}\right]\\&\left[1+\frac{\mathrm{A}(r)^2}{\mathrm{D}(r)^2}\frac{\mathrm{A}(\frac{360}{7})^2}{\mathrm{B}(\frac{360}{7})^2}\right]\\&\left[1+\frac{\mathrm{A}(r)^2}{\mathrm{D}(r)^2}\frac{\mathrm{A}(\frac{540}{7})^2}{\mathrm{B}(\frac{540}{7})^2}\right]\end{aligned}$$

$$\mathrm{ME}(r,7)=\mathrm{E}(r)+3\mathrm{E}(r).$$

$$+\frac{\mathrm{A}(2r)}{\mathrm{D}(0)\mathrm{D}(2r)}\left[\frac{\dfrac{\mathrm{A}(r)^2}{\mathrm{D}(r)^2}+\dfrac{\mathrm{A}(\frac{180}{7})^2}{\mathrm{B}(\frac{180}{7})^2}}{1+\dfrac{\mathrm{A}(r)^2}{\mathrm{D}(r)^2}\dfrac{\mathrm{A}(\frac{180}{7})^2}{\mathrm{B}(\frac{180}{7})^2}}+\frac{\dfrac{\mathrm{A}(r)^2}{\mathrm{D}(r)^2}+\dfrac{\mathrm{A}(\frac{360}{7})^2}{\mathrm{B}(\frac{360}{7})^2}}{1+\dfrac{\mathrm{A}(r)^2}{\mathrm{D}(r)^2}\dfrac{\mathrm{A}(\frac{360}{7})^2}{\mathrm{B}(\frac{360}{7})^2}}+\frac{\dfrac{\mathrm{A}(r)^2}{\mathrm{D}(r)^2}+\dfrac{\mathrm{A}(\frac{540}{7})^2}{\mathrm{B}(\frac{540}{7})^2}}{1+\dfrac{\mathrm{A}(r)^2}{\mathrm{D}(r)^2}\dfrac{\mathrm{A}(\frac{540}{7})^2}{\mathrm{B}(\frac{540}{7})^2}}\right]$$

$$\mathrm{M}=\frac{1+\mathrm{cn}\frac{4}{7}\mathrm{K}}{1-\mathrm{cn}\frac{4}{7}\mathrm{K}}\cdot\frac{1+cn\frac{8}{7}\mathrm{K}}{1-cn\frac{8}{7}\mathrm{K}}\,\frac{1+\mathrm{cn}\frac{12}{7}\mathrm{K}}{1-\mathrm{cn}\frac{12}{7}\mathrm{K}}.$$

The calculation has been made at $r=45$, . . . , so as to show the general shape of the curve of the elliptic function of penultimate character.

Some applications of the Elliptic Function Table were mentioned in Report II., p. 7, including the potential of a spherical bowl, which can be given by $c\Omega+r'\Omega'$ instead of the expansion in a series of spherical harmonics, as in Maxwell's 'Electricity and Magnetism,' II. §694, where it is denoted by P; and then

$$\mathrm{P}r=cr\Omega+c^2\Omega',\ \text{leading to}\ \frac{d}{dr}(\mathrm{P}r)=c\Omega,\ \text{as in §695.}$$

ELLIPTIC FUNCTION TABLE. $\theta = 24^\circ{\cdot}47$; $\sin\theta = \sqrt{2} - 1$.

$K = \frac{1}{\sqrt{2}} K' = 1{\cdot}645608$, $E = 1{\cdot}503401$, $E' = 1{\cdot}158909$, $\frac{1}{q} = e^{\pi\sqrt{2}} = 85{\cdot}02$.

r	$F(\phi)$	ϕ	$E(r)$	$D(r)$	$A(r)$	$B(r)$	$C(r)$	$F(r)$	ψ	$F(\psi)$	$90-r$
		°							°		
0	0·000000	0·00	0·000000	1·00000	0·000000	1·000000	1·04818	0·000000	90·00	1·645608	90
1	0·018285	1·70	0·001605	1·00001	0·017443	0·999571	1·04817	0·001531	89·05	1·627323	89
2	0·036569	2·49	0·003208	1·00006	0·034880	0·999115	1·04812	0·003061	88·10	1·609039	88
3	0·054854	3·42	0·004807	1·00013	0·052307	0·998355	1·04805	0·004587	87·14	1·590754	87
4	0·073138	4·40	0·006399	1·00023	0·069718	0·997288	1·04795	0·006108	86·19	1·572470	86
5	0·091423	5·40	0·007983	1·00037	0·087108	0·995923	1·04782	0·007622	85·23	1·554185	85
6	0·109707	6·42	0·009557	1·00053	0·104471	0·994252	1·04766	0·009127	84·28	1·535901	84
7	0·127992	7·44	0·011118	1·00072	0·121803	0·992280	1·04747	0·010622	83·33	1·517616	83
8	0·146276	8·47	0·012665	1·00093	0·139098	0·990005	1·04725	0·012105	82·37	1·499332	82
9	0·164561	9·50	0·014195	1·00118	0·156350	0·987428	1·04700	0·013574	81·42	1·481047	81
10	0·182845	10·54	0·015707	1·00145	0·173555	0 984552	1·04673	0·015028	80·46	1·462763	80
11	0·201130	11·57	0·017198	1·00176	0·190707	0·981375	1·04643	0·016464	79·50	1·444478	79
12	0·219414	12·61	0·018667	1·00208	0·207802	0·977901	1·04609	0·017882	78·55	1·426194	78
13	0·237699	13·65	0·020112	1·00244	0·224833	0·974128	1·04574	0·019279	77·59	1·407909	77
14	0·255983	14·69	0·021531	1·00282	0·241796	0·970059	1·04536	0·020655	76·63	1·389624	76
15	0·274268	15·72	0·022921	1·00323	0·258686	0·965694	1·04495	0·022006	75·67	1·371340	75
16	0·292553	16·76	0·024282	1·00366	0·275497	0·961036	1·04452	0 023333	74·71	1·353055	74
17	0·310837	17·80	0·025612	1·00412	0·292224	0·956085	1·04406	0·024636	73·75	1·334771	73
18	0·329122	18·83	0·026909	1·00460	0·308862	0·950844	1·04358	0·025904	72·79	1·316486	72
19	0·347406	19·87	0·028171	1·00511	0·325407	0·945312	1·04307	0·027146	71·83	1·298202	71
20	0·365691	20·90	0·029396	1·00564	0·341852	0·939493	1·04254	0·028356	70·86	1·279917	70
21	0·383975	21·93	0·030585	1·00619	0·358195	0·933389	1·04199	0·029534	69·89	1·261633	69

90−r	F(ψ)	ψ	F(r)	C(r)	B(r)	A(r)	D(r)	E(r)	φ	F(φ)	r
22	0·402260	22·96	0·031733	1·00676	0·374428	0·926999	1·04142	0·030677	68·93	1·243348	68
23	0·420544	23·99	0·032841	1·00736	0·390548	0·920328	1·04083	0·031785	67·96	1·225064	67
24	0·438829	25·02	0·033908	1·00797	0·406549	0·913376	1·04021	0·032857	66·99	1·206779	66
25	0·457113	26·05	0·034930	1·00861	0·422426	0·906147	1·03958	0·033890	66·02	1·188495	65
26	0·475398	27·08	0·035909	1·00926	0·438175	0·898641	1·03892	0·034884	65·05	1·170210	64
27	0·493682	28·10	0·036842	1·00993	0·453791	0·890862	1·03825	0·035835	64·08	1·151926	63
28	0·511967	29·13	0·037728	1·01062	0·469269	0·882811	1·03756	0·036748	63·11	1·133641	62
29	0·530251	30·15	0·038566	1·01132	0·484605	0·874491	1·03686	0·037616	62·13	1·115356	61
30	0·548536	31·17	0·039355	1·01205	0·499793	0·865906	1·03614	0·038440	61·16	1·097072	60
31	0·566821	32·19	0·040095	1·01278	0·514829	0·857042	1·03540	0·039219	60·18	1·078787	59
32	0·585105	33·22	0·040785	1·01353	0·529708	0·847916	1·03465	0·039952	59·20	1·060503	58
33	0·603390	34·24	0·041423	1·01429	0·544427	0·838533	1·03389	0·041028	58·22	1·042218	57
34	0·621674	35·26	0·042009	1·01507	0·558980	0·828894	1·03311	0·041639	57·24	1·023934	56
35	0·639959	36·27	0·042543	1·01585	0·573363	0·819003	1·03233	0·042201	56·25	1·005649	55
36	0·658243	37·29	0·043024	1·01665	0·587572	0·808862	1·03154	0·042709	55·27	0·987365	54
37	0·676528	38·30	0·043451	1·01745	0·601603	0·798475	1·03073	0·043167	54·28	0·969080	53
38	0·694812	39·31	0·043824	1·01826	0·615450	0·787846	1·02992	0·043573	53·30	0·950796	52
39	0·713097	40·32	0·044144	1·01906	0·629110	0·776976	1·02910	0·043714	52·31	0·932511	51
40	0·731381	41·33	0·044408	1·01991	0·642579	0·765869	1·02827	0·044047	51·32	0·914227	50
41	0·749666	42·33	0·044618	1·02074	0·655852	0·754530	1·02744	0·044327	50·33	0·895942	49
42	0·767950	43·34	0·044774	1·02157	0·668926	0·742961	1·02661	0·044554	49·34	0·877658	48
43	0·786235	44·34	0·044873	1·02241	0·681797	0·731165	1·02577	0·044726	48·34	0·859373	47
44	0·804519	45·35	0·044918	1·02325	0·694460	0·719148	1·02493	0·044845	47·35	0·841089	46
45	0·822804	46·35	0·044909	1·02409	0·706911	0·706911	1·02409	0·044909	46·35	0·822804	45

ELLIPTIC FUNCTION TABLE. $\theta = 65^\circ{\cdot}53$; $\cos\theta = \sqrt{2} - 1$.

$K = \sqrt{2}\,K' = 2{\cdot}327399$, $E = 1{\cdot}158909$, $E' = 1{\cdot}503401$, $\frac{1}{q} = e^{\frac{\pi}{\sqrt{2}}} = 9{\cdot}2206$.

r	F (ϕ)	ϕ	E (r)	D (r)	A (r)	B (r)	C (r)	F (r)	ψ	F (ψ)	90—r
		°							°		
0	0·000000	0·00	0·000000	1·00000	0·000000	1·000000	1·55377	0·000000	90·00	2·327399	90
1	0·025860	1·48	0·012975	1·00017	0·016641	0·999833	1·55363	0·008438	89·39	2·301539	89
2	0·051720	2·96	0·025921	1·00067	0·033279	0·999334	1·55312	0·016872	88·77	2·275679	88
3	0·077580	4·44	0·038811	1·00151	0·049909	0·998502	1·55226	0·025296	88·16	2·249819	87
4	0·103440	5·92	0·051614	1·00268	0·066528	0·997338	1·55107	0·033705	87·54	2·223959	86
5	0·129300	7·39	0·064306	1·00419	0·083134	0·995843	1·54955	0·042095	86·93	2·198099	85
6	0·155160	8·86	0·076857	1·00602	0·099720	0·994016	1·54769	0·050459	86·31	2·172239	84
7	0·181020	10·32	0·089240	1·00818	0·116286	0·991860	1·54551	0·058794	85·69	2·146379	83
8	0·206880	11·78	0·101432	1·01067	0·132827	0·989376	1·54300	0·067094	85·06	2·120519	82
9	0·232740	13·23	0·113406	1·01348	0·149338	0·986564	1·54015	0·075353	84·44	2·094659	81
10	0·258600	14·68	0·125138	1·01662	0·165817	0·983427	1·53699	0·083568	83·81	2·068799	80
11	0·284460	16·12	0·136606	1·02006	0·182259	0·979965	1·53351	0·091731	83·18	2·042939	79
12	0·310320	17·55	0·147789	1·02382	0·198662	0·976181	1·52972	0·099839	82·54	2·017079	78
13	0·336180	18·97	0·158665	1·02789	0·215020	0·972077	1·52561	0·107886	81·90	1·991219	77
14	0·362040	20·38	0·169217	1·03225	0·231331	0·967655	1·52121	0·115865	81·25	1·965359	76
15	0·387900	21·78	0·179425	1·03692	0·247589	0·962917	1·51650	0·123772	80·60	1·939499	75
16	0·413760	23·16	0·189275	1·04186	0·263794	0·957865	1·51151	0·131600	79·95	1·913639	74
17	0·439620	24·54	0·198750	1·04712	0·279938	0·952503	1·50622	0·139338	79·29	1·887779	73
18	0·465480	25·91	0·207838	1·05264	0·296020	0·946833	1·50065	0·146998	78·62	1·861919	72
19	0·491340	27·26	0·216534	1'05843	0·312034	0·940858	1·49481	0·154554	77·95	1·836059	71
20	0·517200	28·60	0·224806	1·06449	0·327976	0·934581	1·48870	0·162007	77·27	1·810199	70
21	0·543060	29·93	0·232666	1·07080	0·343844	0·928005	1·48234	0·169351	76·59	1·784339	69

90−r	F (ψ)	ψ	F (r)	C (r)	B (r)	A (r)	D (r)	E (r)	φ	F (φ)	r
22	0·568920	31·24	0·240099	1·07737	0·359632	0·921133	1·47572	0·176580	75·90	1·758479	68
23	0·594780	32·54	0·247099	1·08418	0·375336	0·913970	1·46886	0·183685	75·20	1·732619	67
24	0·620640	33·83	0·253662	1·09122	0·390952	0·906518	1·46177	0·190659	74·49	1·706759	66
25	0·646500	35·10	0·259784	1·09849	0·406476	0·898781	1·45445	0·197496	73·77	1·680899	65
26	0·672360	36·35	0·265461	1·10598	0·421904	0·890762	1·44692	0·204189	73·05	1·655040	64
27	0·698220	37·59	0·270859	1·11367	0·437230	0·882467	1·43917	0·210730	72·31	1·629180	63
28	0·724080	38·81	0·275479	1·12159	0·452452	0·873898	1·43123	0·217112	71·57	1·603320	62
29	0·749940	40·02	0·279822	1·12965	0·467564	0·865061	1·42311	0·223325	70·82	1·577460	61
30	0·775800	41·22	0·283722	1·13791	0·482562	0·855957	1·41480	0·229363	70·06	1·551600	60
31	0·801660	42·40	0·287183	1·14635	0·497441	0·846594	1·40633	0·235218	69·28	1·525740	59
32	0·827520	43·56	0·290210	1·15494	0·512197	0·836974	1·39770	0·240880	68·50	1·499880	58
33	0·853380	44·70	0·292805	1·16368	0·526825	0·827102	1·38892	0·246340	67·71	1·474020	57
34	0·879240	45·83	0·294962	1·17256	0·541321	0·816985	1·38000	0·251580	66·91	1·448160	56
35	0·905100	46·95	0·296724	1·18156	0·555679	0·806620	1·37096	0·256625	66·09	1·422300	55
36	0·930960	48·05	0·298061	1·19069	0·569896	0·796019	1·36181	0·261430	65·26	1·396440	54
37	0·956820	49·13	0·298994	1·19991	0·583966	0·785185	1·35255	0·265998	64·42	1·370580	53
38	0·982680	50·20	0·299528	1·20924	0·597884	0·774121	1·34321	0·270320	63·57	1·344720	52
39	1·008540	51·25	0·299674	1·21864	0·611646	0·762834	1·33378	0·274386	62·71	1·318860	51
40	1·034400	52·28	0·299438	1·22812	0·625247	0·751326	1·32428	0·278187	61·83	1·293000	50
41	1·060260	53·30	0·298830	1·23766	0·638682	0·739602	1·31473	0·281712	60·94	1·267140	49
42	1·086120	54·31	0·297860	1·24724	0·651947	0·727672	1·30513	0·284953	60·03	1·241280	48
43	1·111980	55·30	0·296538	1·25687	0·665035	0·715536	1·29550	0·287899	59·11	1·215420	47
44	1·137840	56·27	0·294868	1·26652	0·677943	0·703198	1·28584	0·290540	58·18	1·189560	46
45	1·163700	57·23	0·292866	1·27618	0·690666	0·690666	1·27618	0·292866	57·23	1·163700	45

ELLIPTIC FUNCTION TABLE. $\theta = 81^\circ{\cdot}83$; $\sin\theta = (\sqrt{2} - 1)^3 (2 + \sqrt{3})^2$.

$K = \frac{3}{\sqrt{2}} K' = 3{\cdot}350392$, $E = 1{\cdot}033611$, $E' = 1{\cdot}562819$, $\frac{1}{q} = e^{\frac{1}{3}\pi\sqrt{2}} = 4{\cdot}397170$.

r	F (ϕ)	ϕ	E (r)	D (r)	A (r)	B (r)	C (r)	F (r)	ψ	F (ψ)	90—r
0	0·000000	0·00	0·000000	1·00000	0·000000	1·000000	2·65164	0·000000	90·00	3·350392	90
1	0·037227	2·58	0·025758	1·00048	0·014030	0 999453	2·65109	0·010679	89·69	3·313165	89
2	0·074453	4·51	0·051417	1·00192	0·028107	0 998814	2·64952	0·021855	89·39	3·275939	88
3	0·111680	6·54	0·076875	1·00430	0·042098	0·997761	2·64690	0·032031	89·09	3·238712	87
4	0·148906	8·63	0·102035	1·00766	0·056140	0·996271	2·64322	0·042699	88·78	3·201486	86
5	0·186133	10·72	0·126803	1·01197	0·070189	0·994378	2·63851	0·053358	88·48	3·164259	85
6	0·223359	12·80	0·151091	1·01722	0·084247	0·991881	2·63277	0·064013	88·17	3·127033	84
7	0·260586	14·85	0·174810	1·02341	0·098316	0·989318	2·62600	0·074642	87·86	3·089806	83
8	0·297813	16·88	0·197884	1·03053	0·112397	0·986167	2·61822	0·085263	87·54	3·052579	82
9	0·335039	18·90	0·220239	1·03858	0·126493	0·982600	2·60943	0·095866	87·22	3·015353	81
10	0·372266	20·90	0·241840	1·04756	0·140603	0·978637	2·59964	0·106456	86·90	2·978126	80
11	0·409492	22·88	0·262536	1·05744	0·154731	0·974271	2·58887	0·117012	86·57	2·940900	79
12	0·446719	24·83	0·282365	1·06822	0·168874	0·969485	2·57713	0·127551	86·24	2·903673	78
13	0·483946	26·75	0·301260	1·07989	0·183036	0·964344	2·56447	0·138057	85·90	2·866446	77
14	0·521172	28·63	0·319128	1·09263	0·197218	0·958800	2·55085	0·148537	85·56	2·829220	76
15	0·558399	30·49	0·336093	1·10584	0·211418	0·952878	2·53632	0·158981	85·21	2·791993	75
16	0·595625	32·32	0·351985	1·12009	0·225637	0 946577	2·52092	0 169388	84·86	2·754767	74
17	0·632852	34·11	0·366836	1·13518	0·239878	0·939914	2·50461	0·179760	84·50	2·717540	73
18	0·670078	35·86	0·380640	1·15109	0·254136	0·932878	2·48747	0·190078	84·13	2·680314	72
19	0·707305	37·58	0·393396	1·16779	0·268413	0·925496	2·46950	0·200352	83·76	2·643087	71
20	0·744532	39·26	0·405107	1·18528	0·282707	0·917772	2·45072	0·210574	83·38	2·605860	70
21	0·781758	40·90	0·415784	1·20353	0·297018	0·909697	2·43117	0·220739	82·99	2·568634	69

$90-r$	$F(\psi)$	ψ	$F(r)$	$C(r)$	$B(r)$	$A(r)$	$D(r)$	$E(r)$	ϕ	$F(\phi)$	r
22	0·818985	42·50	0·425447	1·22248	0·311345	0·901301	2·41086	0·230843	82·59	2·531407	68
23	0·856211	44·06	0·434086	1·24223	0·325684	0·892575	2·38983	0·240880	82·17	2·494181	67
24	0·893438	45·59	0·441753	1·26265	0·340036	0·883542	2·36811	0·250846	81·74	2·456954	66
25	0·930664	47·08	0·448460	1·28374	0·354398	0·874201	2·34571	0·260734	81·31	2·419728	65
26	0·967891	48·53	0·454236	1·30549	0·368767	0·864558	2·32267	0·270539	80·87	2·382501	64
27	1·005118	49·94	0·459109	1·32787	0·383139	0·854630	2·29902	0·280251	80·41	3·345274	63
28	1·042344	51·31	0·463110	1·35086	0·397512	0·844425	2·27480	0·289871	79·94	2·308048	62
29	1·079571	52·64	0·466270	1·37442	0·411884	0·833957	2·25004	0·299383	79·45	2·270821	61
30	1·116797	53·94	0·468623	1·39854	0·426248	0·823222	2·22475	0·308784	78·95	2·233595	60
31	1·154024	55·20	0·470195	1·42319	0·440592	0·812218	2·19896	0·318062	78·44	2·196368	59
32	1·191250	56·42	0·471026	1·44834	0·454942	0·800979	2·17271	0·327213	77·92	2·159141	58
33	1·228477	57·61	0·471150	1·47396	0·469260	0·789510	2·14605	0·336798	77·38	2·121915	57
34	1·265704	58·76	0·470600	1·50002	0·483554	0·777817	2·11902	0·345618	76·82	2·084688	56
35	1·302930	59·88	0·469409	1·52649	0·497819	0·766142	2·09234	0·354099	76·24	2·047462	55
36	1·340157	60·97	0·467610	1·55333	0·512046	0·753810	2·06396	0·362758	75·64	2·010235	54
37	1·377383	62·02	0·465233	1·58053	0·526232	0·741514	2·03600	0·371054	75·02	1·973009	53
38	1·414610	63·04	0·462310	1·60805	0·540371	0·729035	2·00780	0·379151	74·39	1·935782	52
39	1·451837	64·03	0·458873	1·63585	0·554453	0·716385	1·97941	0·386720	73·74	1·898555	51
40	1·489063	64·99	0·454945	1·66391	0·568473	0·703572	1·95085	0·394123	73·06	1·861329	50
41	1·526290	65·92	0·450560	1·69218	0·582424	0·690608	1·92215	0·401882	72·36	1·824102	49
42	1·563516	66·81	0·445742	1·72064	0·596301	0·677497	1·89336	0·409082	71·64	1·786876	48
43	1·600743	67·67	0·440513	1·74925	0·610092	0·664251	1·86452	0·416002	70·90	1·749649	47
44	1·637969	68·51	0·434903	1·77798	0·623792	0·650878	1·83565	0·422627	70·13	1·712423	46
45	1·675196	69·33	0·428935	1·80679	0·637387	0 637387	1·80679	0·428935	69·33	1·675196	45

ELLIPTIC FUNCTION TABLE. $\theta = 87^\circ{\cdot}3$; $\cos\theta = (\sqrt{2} + 1 - \sqrt{2\sqrt{2}+2})^2 = \left(\frac{\sqrt{\sqrt{2}+1}}{\sqrt[4]{2}}\right)^4$

$K = 2\sqrt{2}\,K' = 4{\cdot}461893$, $E = 1{\cdot}00444$, $E' = 1{\cdot}56990$, $\frac{1}{q} = e^{\frac{\pi}{2\sqrt{2}}} = 3{\cdot}036544$

r	F (φ)	φ	E (r)	D (r)	A (r)	B (r)	C (r)	F (r)	ψ	F (ψ)	90−r
0	0·000000	0·00°	0·000000	1·00000	0·000000	1·000000	4·61158	0·000000	90·00°	4·461893	90
1	0·049577	2·84	0·038191	1·00095	0·010712	0·999725	4·61032	Constant difference 0·0109	89·87	4·412317	89
2	0·099153	5·63	0·076143	1·00377	0·021432	0·998931	4·60655		89·74	4·362740	88
3	0·148730	8·46	0·113622	1·00849	0·032170	0·997523	4·60027		89·61	4·313164	87
4	0·198306	11·25	0·150402	1·01510	0·042932	0·995600	4·59149		89·47	4·263587	86
5	0·247883	14·01	0·186268	1·02358	0·053728	0·993133	4·58023		89·33	4·214010	85
6	0·297460	16·74	0·221027	1·03393	0·064566	0·990126	4·56650		89·19	4·164434	84
7	0·347036	19·43	0·254502	1·04614	0·075454	0·986584	4·55033		89·05	4·114857	83
8	0·396613	22·07	0·286542	1·06023	0·086399	0·982513	4·53176		88·91	4·065281	82
9	0·446189	24·67	0·317006	1·07616	0·097409	0·977917	4·51080		88·76	4·015704	81
10	0·495766	27·22	0·345797	1·09393	0·108492	0·972806	4·48749		88·61	3·966127	80
11	0·545343	29·71	0·372829	1·11352	0·119654	0·967187	4·46186		88·46	3·916551	79
12	0·594919	32·13	0·398042	1·13493	0·130903	0·961069	4·43398		88·31	3·866974	78
13	0·644496	34·50	0·421399	1·15814	0·142245	0·954461	4·40387		88·15	3·817398	77
14	0·694072	36·80	0·442884	1·18314	0·153685	0·947374	4·37160		87·99	3·767821	76
15	0·743649	39·03	0·462499	1·20990	0·165230	0·939819	4·33720		87·82	3·718244	75
16	0·793225	41·20	0·480265	1·23839	0·176883	0·931814	4·30078		87·64	3·668668	74
17	0·842802	43·30	0·496208	1·26865	0·188655	0·923350	4·26228		87·46	3·619091	73
18	0·892379	45·32	0·510394	1·30056	0·200545	0·914461	4·22188		87·28	3·569515	72
19	0·941955	47·28	0·522861	1·33428	0·212557	0·905154	4·17959		87·09	3·519938	71
20	0·991532	49·17	0·533681	1·36950	0·224696	0·895441	4·13550		86·89	3·470361	70
21	1·041108	50·99	0·542924	1·40641	0·236964	0·885339	4·08969		86·68	3·420785	69

90−r	Fψ	ψ	F(r)	C(r)	B(r)	A(r)	D(r)	E(r)	φ	Fφ	r
22	1·090685	52·74	0·550665	1·44493	0·249365	0·874862	4·04220		86·46	3·371208	68
23	1·140262	54·42	0·556984	1·48500	0·261899	0·864023	3·99311		86·23	3·321632	67
24	1·189838	56·04	0·561960	1·52662	0·274568	0·852840	3·94251		86·00	3·272055	66
25	1·239415	57·59	0·565672	1·56974	0·287372	0·841328	3·89048		85·76	3·222478	65
26	1·288991	59·08	0·568200	1·61433	0·300312	0·829502	3·83709		85·51	3·172902	64
27	1·338568	60·51	0 569622	1·66034	0·313387	0·817380	3·78241		85·25	3·123325	63
28	1·388145	61·88	0·569669	1·70774	0·326596	0·804978	3·72656		84·97	3·073749	62
29	1·437721	63·19	0·569446	1·75649	0·339937	0·792312	3·66959		84·68	3·024172	61
30	1·487298	64·44	0·567991	1·80654	0·353407	0·779399	3·61159	0·327843	84·38	2·974596	60
31	1·536874	65·64	0·565715	1·85784	0·367003	0·766256	3·55265	0·338394	84·07	2·925019	59
32	1·586451	66·79	0·562679	1·91035	0·380722	0·752900	3·49287	0·348889	83·74	2·875442	58
33	1·636028	67·88	0·558945	1·96402	0·394559	0·739346	3·43230	0·359321	83·40	2·825866	57
34	1·685604	68·93	0·554565	2·01878	0·408508	0·725615	3·37107	0·369682	83·04	2·776289	56
35	1·735181	69·93	0·549595	2·07459	0·422564	0·711717	3·30923	0·379970	82·66	2·726713	55
36	1·784757	70·89	0·544082	2·13139	0·436722	0·697674	3·24689	0·390172	82·27	2·677136	54
37	1·834334	71·81	0·538067	2·18913	0·450972	0·683501	3·18411	0·400279	81·86	2·627559	53
38	1·883910	72·68	0·531604	2·24774	0·465308	0·669213	3·12101	0·410291	81·42	2·577983	52
39	1·933487	73·51	0·524721	2·30715	0·479721	0·654826	3·05765	0·420187	80·96	2·528406	51
40	1·983064	74·31	0·517457	2·36731	0·494203	0·640356	2·99411	0·429959	80·49	2·478830	50
41	2·032640	75·07	0·509845	2·42814	0·508743	0·625817	2·93050	0·439596	80·00	2·429253	49
42	2·082217	75·79	0·501905	2·48958	0·523331	0·611226	2·86689	0·449082	79·48	2·379676	48
43	2·131793	76·48	0·493695	2·55155	0·537956	0·596596	2·80334	0·458405	78·93	2·330100	47
44	2·181370	77·14	0·485196	2·61400	0·552608	0·581941	2·73997	0·467531	78·36	2·280523	46
45	2·230947	77·77	0·476489	2·67683	0·567274	0·567274	2·67683	0·476489	77·77	2·230947	45

ELLIPTIC FUNCTION TABLE.

$$\theta = 87^\circ\ 56',\ \sin 2\theta = (2 \sin 15^\circ)^4,\ \cos\theta = (\sqrt{3}-1)\frac{\sqrt{2}-\sqrt[4]{3}}{2},\ \cos(\theta - 45^\circ) = \sqrt{3}-1.$$

$$K = 4{\cdot}7427173 = 3K',\qquad E = 1{\cdot}0026804,\qquad E' = 1{\cdot}3252151,\qquad \frac{1}{q} = e^{\frac{1}{3}\pi} = 2{\cdot}849654.$$

r	F (φ)	φ	E (r)	D (r)	A (r)	B (r)	C (r)	F (r)	ψ	F (ψ)	90−r
		°							°		
0	0·0000000	0·00	0 0000000	1·00000	0 0000000	1·000000	5·27621	0·0000000	90·00	4·7427173	90
1	0·0526969	3·02	0·0410591	1·00108	0·0099287	0·994589	5·27075	0·0110807	89·89	4·6900204	89
2	0·1053937	6·03	0·0818324	1·00435	0·0198676	0·993743	5·26261	0·0221617	89·78	4·6373235	88
3	0·1580906	9·02	0·122049	1·00972	0·0298256	0·992324	5·25182	0·0332411	89·67	4·5846267	87
4	0·2107874	11·99	0·161437	1·01727	0·0398133	0·990360	5·23841	0·0443202	89·56	4·5319298	86
5	0·2634843	14·92	0·199752	1·02697	0·0498403	0·987802	5·22242	0·0553968	89·45	4·4792330	85
6	0·3161812	17·82	0·236766	1·03882	0·0599163	0·984705	5·20387	0·0664708	89·34	4·4265361	84
7	0·3688780	20·67	0·272280	1·05281	0·0700497	0·981064	5·18278	0·0775431	89·23	4·3738393	83
8	0·4215749	23·47	0·306121	1·06893	0·0802512	0·976865	5·15918	0·0886119	89·12	4·3211424	82
9	0·4742717	26·21	0·338146	1·08718	0·0905287	0·972094	5·13308	0·0996761	89·00	4·2684455	81
10	0·5269686	28·89	0·368230	1·10755	0 100891	0·966877	5·10450	0·110737	88·88	4·2157487	80
11	0·5796654	31·50	0·396332	1·13002	0·111347	0·961099	5·07346	0·121792	88·75	4·1630518	79
12	0·6323623	34·04	0·422353	1·15458	0·121904	0·954803	5·03998	0·132842	88·62	4·1103550	78
13	0·6850592	36·50	0·446475	1·18123	0·132568	0·948000	5·00407	0·143885	88·49	4·0576581	77
14	0·7377560	38·89	0·468119	1·20993	0·143353	0·940684	4·96576	0·154618	88·36	4·0049612	76
15	0·7904529	41·20	0·487891	1·24069	0·154259	0·932940	4·92507	0·165950	88·23	3·9522644	75
16	0·8431497	43·43	0·505621	1·27348	0·165295	0·924703	4·88198	0·176970	88·09	3·8995675	74
17	0·8958466	45·58	0·521369	1·30827	0·176467	0·916007	4·83652	0·187979	87·94	3·8468707	73
18	0·9485435	47·76	0·535202	1·34506	0·187781	0·906864	4·78876	0·198978	87·79	3·7941738	72
19	1·0012403	49·66	0·547197	1·38381	0·199240	0·897310	4·73880	0·209963	87·63	3·7414770	71
20	1·0539372	51·58	0·557438	1·42451	0·210852	0·887331	4·68670	0·220936	87·46	3·6887801	70
21	1·1066340	53·42	0 566022	1·46712	0·222618	0·876952	4·63255	0·231895	87·29	3·6360832	69

90 − r	F (ψ)	ψ	F (r)	C (r)	B (r)	A (r)	D (r)	E (r)	φ	F (φ)	r
22	1·1593309	55·18	0·573031	1·51161	0·234542	0·866197	4·57643	0·242836	87·11	3·5833864	68
23	1·2120277	56·87	0·578564	1·55796	0·246627	0·855067	4·51845	0·253758	86·92	3·5306895	67
24	1·2647246	58·49	0·582717	1·60613	0·258874	0·843600	4·45867	0·264381	86·72	3·4779927	66
25	1·3174215	60·03	0·585582	1·65608	0·271286	0·831796	4·39720	0·275539	86·51	3·4252958	65
26	1·3701183	61·50	0·587248	1·70779	0·283863	0·819668	4·33414	0·286394	86·30	3·3725989	64
27	1·4228152	62·91	0·587805	1·76119	0·296605	0·807242	4·26957	0·297222	86·08	3·3199021	63
28	1·4755120	64·26	0·587336	1·81627	0·309511	0·794532	4·20360	0·308018	85·85	3·2672052	62
29	1·5282089	65·54	0·585920	1·87296	0·322580	0·781564	4·13633	0·318781	85·60	3·2145084	61
30	1·5809058	66·77	0·583634	1·93123	0·335811	0·768350	4·06786	0·329507	85·34	3·1618115	60
31	1·6336026	67·94	0·580451	1·99102	0·349201	0·754780	3·99714	0·340204	85·07	3·1091147	59
32	1·6862995	69·05	0·576537	2·05228	0·362745	0·740808	3·92545	0·350855	84·78	3·0564178	58
33	1·7389963	70·11	0·571980	2·11482	0·376411	0·726750	3·85290	0·361450	84·47	3·0037209	57
34	1·7916932	71·12	0·566762	2·17897	0·390278	0·712523	3·77960	0·372002	84·15	2·9510241	56
35	1·8443900	72·08	0·561012	2·24429	0·404258	0·698147	3·70565	0·382486	83·81	2·8983272	55
36	1·8970869	72·99	0·554755	2·31084	0·418371	0·683631	3·63116	0·392902	83·45	2·8456304	54
37	1·9497838	73·85	0·548035	2·37855	0·432609	0·669016	3·55624	0·403241	83·07	2·7929335	53
38	2·0024806	74·66	0·540896	2·44736	0·446967	0·654296	3·48098	0·413498	82·67	2·7402366	52
39	2·0551775	75·43	0·533376	2·51720	0·461435	0·639495	3·40549	0·423661	82·25	2·6875398	51
40	2·1078743	76·16	0·525518	2·58794	0·476001	0·624637	3·32987	0·433721	81·81	2·6348429	50
41	2·1605712	76·85	0·517333	2·65964	0·490659	0·609722	3·25423	0·443667	81·35	2·5821461	49
42	2·2132681	77·51	0·508872	2·73208	0·505395	0·594795	3·17867	0·453486	80·87	2·5294492	48
43	2·2659649	78·14	0·500152	2·80525	0·520200	0·579850	3·10326	0·463165	80·37	2·4767523	47
44	2·3186618	78·74	0·491200	2·87904	0·535061	0·564934	3·02813	0·472292	79·85	2·4240555	46
45	2·3713586	79·31	0·482040	2·95336	0·549964	0·549964	2·95336	0·482040	79·31	2·3713586	45

ELLIPTIC FUNCTION TABLE. $\theta = 89°$; $\cos\theta = (\sqrt{3} - \sqrt{2})^2(\sqrt{2} - 1)^2$.

$K = 2\sqrt{3}\,K' = 5{\cdot}44100$, $E = 1{\cdot}00075$, $E' = 1{\cdot}57068$, $\frac{1}{q} = e^{\frac{\pi}{2\sqrt{3}}} = 2{\cdot}476633$.

r	F (φ)	φ	E (r)	D (r)	A (r)	B (r)	C (r)	F (r)	ψ	F (ψ)	90—r
0	0·000000	0·00°	0·000000	1·00000	0·000000	1·000000	7·59575	0·000000	90·00°	5·441000	90
1	0·060456	3·48	0·049271	1·00149	0·007962	0·999664	7·59320	0·011101	89·94	5·380544	89
2	0·120911	6·93	0·098104	1·00597	0·015938	0·998656	7·58556	0·022202	89·88	5·320089	88
3	0·181367	10·34	0·146072	1·01344	0·023955	0·996979	7·57284	0·033303	89·82	5·259633	87
4	0·241822	13·71	0·192774	1·02382	0·031980	0·994636	7·55508	0·044403	89·76	5·199178	86
5	0·302278	17·04	0·237842	1·03729	0·040073	0·991631	7·53229	0·055503	89·70	5·138722	85
6	0·362733	20·32	0·280865	1·05370	0·048230	0·987971	7·50454	0·066602	89·64	5·078267	84
7	0·423189	23·54	0·321838	1·07309	0·056464	0·983662	7·47187	0·077700	89·57	5·017811	83
8	0·483644	26·68	0·360270	1·09547	0·064787	0·978714	7·43435	0·088798	89·50	4·957356	82
9	0·544100	29·74	0·396086	1·12082	0·073212	0·973136	7·39206	0·099894	89·43	4·896900	81
10	0·604556	32·71	0·429171	1·14915	0·081750	0·966939	7·34509	0·110988	89·36	4·836444	80
11	0·665011	35·58	0·459464	1·18046	0·090412	0·960135	7·29351	0·122081	89·29	4·775989	79
12	0·725467	38·34	0·486947	1·21460	0·099159	0·952739	7·23745	0·133172	89·22	4·715533	78
13	0·785922	41·00	0·511643	1·24835	0·107977	0·944762	7·17699	0·144261	89·14	4·655078	77
14	0·846378	43·56	0·533609	1·29220	0·117257	0·936223	7·11228	0·155347	89·06	4·594622	76
15	0·906833	46·02	0·552935	1·33537	0·126526	0·927135	7·04343	0·166430	88·97	4·534167	75
16	0·967289	48·38	0·569721	1·38149	0·135971	0·917519	6·97057	0·177510	88·88	4·473711	74
17	1·027744	50·63	0·584079	1·43055	0·145600	0·907390	6·89384	0·188607	88·79	4·413256	73
18	1·088200	52·78	0·596205	1·48253	0·155423	0·896768	6·81340	0·199658	88·70	4·352800	72
19	1·148656	54·82	0·606180	1·53743	0·165447	0·885674	6·72939	0·210726	88·60	4·292344	71
20	1·209111	56·77	0·614171	1·59522	0·175678	0·874126	6·64197	0·226954	88·49	4·231889	70
21	1·269567	58·62	0·620326	1·65590	0·186125	0·862147	6·55130	0·232843	88·38	4·171433	69

90−r	F (ψ)	ψ	F (r)	C (r)	B (r)	A (r)	D (r)	E (r)	φ	F (φ)	r
22	1·330022	60·38	0·624787	1·71944	0·196792	0·849757	6·45756	0·243892	88·26	4·110978	68
23	1·390478	62·05	0·627696	1·78580	0·207684	0·836983	6·36091	0·254931	88·13	4·050522	67
24	1·450933	63·63	0·629185	1·85498	0·218806	0·823842	6·26152	0·265965	88·00	3·990067	66
25	1·511389	65·13	0·629380	1·92693	0·230162	0·810358	6·15958	0·276987	87·86	3·929611	65
26	1·571844	66·55	0·628401	2·00163	0·241754	0·796555	6·05526	0·287998	87·72	3·869156	64
27	1·632300	67·90	0·626358	2·07903	0·253585	0·782456	5·94875	0·298996	87·57	3·808700	63
28	1·692756	69·17	0·623355	2·15909	0·265655	0·768085	5·84023	0·309980	87·40	3·748244	62
29	1·753211	70·37	0·619486	2·24176	0·277965	0·753466	5·72989	0·320948	87·22	3·687789	61
30	1·813667	71·50	0·614837	2·32701	0·290515	0·738622	5·61790	0·331898	87·03	3·627333	60
31	1·874122	72·57	0·609488	2·41477	0·303302	0·723576	5·50447	0·342826	86·83	3·566878	59
32	1·934578	73·57	0·603512	2·50497	0·316326	0·708353	5·38976	0·353732	86·63	3·506422	58
33	1·995033	74·52	0·596974	2·59756	0·329582	0·692976	5·27398	0·364611	86·41	3·445967	57
34	2·055489	75·42	0·589933	2·69247	0·343066	0·677466	5·15728	0·375461	86·18	3·385511	56
35	2·115944	76·27	0·582443	2·78962	0·356774	0·661847	5·03987	0·386277	85·94	3·325056	55
36	2·176400	77·07	0·574551	2·88892	0·370699	0·646143	4·92192	0·397056	85·68	3·264600	54
37	2·236856	77·82	0·566302	2·99031	0·384835	0·630374	4·80360	0·407792	85·41	3·204144	53
38	2·297311	78·53	0·557734	3·09368	0·399173	0·614562	4·68509	0·418481	85·12	3·143689	52
39	2·357767	79·21	0·548881	3·19893	0·413705	0·598727	4·56656	0·429115	84·81	3·083233	51
40	2·418222	79·85	0·539776	3·30597	0·428421	0·582892	4·44818	0·439688	84·48	3·022778	50
41	2·478678	80·45	0·530446	3·41469	0·443310	0·567073	4·33010	0·450193	84·13	2·962322	49
42	2·539133	81·01	0·520916	3·52497	0·458361	0·551293	4·21249	0·460619	83·76	2·901867	48
43	2·599589	81·54	0·511207	3·63670	0·473561	0·535567	4·09551	0·470961	83·37	2·841411	47
44	2·660044	82·03	0·501341	3·74975	0·488896	0·519915	3·97929	0·481203	82·95	2·780956	46
45	2·720500	82·50	0·491334	3·86399	0·504352	0·504352	3·86399	0·491334	82·50	2·720500	45

ELLIPTIC FUNCTION TABLE. $\text{Cos}\ \theta = \left(\frac{\sqrt[4]{2}-1}{\sqrt[4]{2}+1}\right)^2.$

$K = 4K' = 6{\cdot}283185, \quad E = 1{\cdot}000322, \quad E' = 1{\cdot}570745, \quad \frac{1}{q} = e^{\frac{1}{4}\pi} = 2{\cdot}19328.$

r	F ϕ	ϕ	E (r)	D (r)	A (r)	B (r)	C (r)	F (r)	ψ	F (ψ)	90 − r
0	0·000000	0° 00	0 000000	1 00000	0 000000	1·000000	11·56950	0·000000	90°·00	6·283185	90
1	0·069813	6·36	0·058587	1·00206	0·006036	0·995889	11·55830	Constant difference 0·0110	89·97	6·213372	89
2	0·139626	9·38	0·116502	1·00824	0·012089	0·994767	11·53870		89·94	6·143559	88
3	0·209440	12·88	0·173094	1·01845	0·018171	0·992839	11·51080		89·91	6·073746	87
4	0·279253	16·52	0·227766	1 03281	0·024299	0·990190	11·47480		89·88	6·003933	86
5	0·349066	20·18	0·279987	1·05131	0·030489	0·986768	11·43080		89·85	5·934119	85
6	0·418879	23·80	0·329314	1·07392	0·036754	0·982612	11·37890		89·81	5·864306	84
7	0·488692	27·34	0·375395	1·10068	0·043111	0·977730	11·31920		89·78	5·794493	83
8	0·558505	30·79	0·417972	1 13162	0·049574	0·972119	11·25180		89·75	5·724680	82
9	0·628319	34·13	0·456887	1·16674	0 056157	0·965801	11·17780		89·72	5·654867	81
10	0·698132	37·35	0·492061	1·20606	0 062874	0·958793	11·09540		89·68	5·585054	80
11	0·767945	40·44	0·522557	1·24961	0·069740	0·951106	11·00570		89·64	5·515240	79
12	0·837758	43·39	0·551278	1·29741	0·076768	0·942754	10·90870		89·60	5·445427	78
13	0·907571	46·22	0·575511	1 34947	0·083971	0·933754	10·80450		89·56	5·375614	77
14	0·977384	48·91	0·596368	1·40586	0·091364	0·924117	10·69330		89·51	5·305801	76
15	1·047198	51·46	0·614039	1 46655	0·098957	0·913911	10·57520		89·46	5·235988	75
16	1·117011	53·87	0·628582	1·53160	0·106763	0·903106	10·45040		89·41	5·166175	74
17	1·186824	56·15	0·640369	1·60102	0·114793	0·891742	10·31880		89·36	5·096361	73
18	1·256637	58·31	0·649661	1 67483	0·123059	0·879840	10·18120		89·31	5·026548	72
19	1·326450	60·34	0·656602	1·75305	0·131571	0·867442	10·03790		89·25	4·956735	71
20	1·396263	62·26	0·661632	1 83572	0·140340	0·854553	9·88887		89·18	4·886922	70
21	1·466077	64·06	0·664742	1 92282	0 149373	0 841204	9·73455		89·11	4·817109	69

90−r	Fψ	ψ	F(r)	C(r)	B(r)	A(r)	D(r)	E(r)	φ	Fφ	r
22	1·535890	65·75	0·666197	2·01440	0·158680	0·827433	9·57537	Constant difference 0·0110	89·03	4·747296	68
23	1·605703	67·34	0·666178	2·11043	0·168269	0·813251	9·41145		88·96	4·677482	67
24	1·675516	68·82	0·664860	2·21093	0·178146	0·798705	9·24332		88·88	4·607669	66
25	1·745329	70·21	0·662381	2·31590	0·188318	0·783814	9·07123		88·80	4·537856	65
26	1·815142	71·52	0·658956	2·42534	0·198791	0·768606	8·89550		88·71	4·468043	64
27	1·884956	72·75	0·654456	2·53922	0·209569	0·753110	8·71647		88·62	4·398230	63
28	1·954769	73·89	0·649244	2·65753	0·220656	0·737349	8·53441		88·52	4·328417	62
29	2·024582	74·96	0·643324	2·78031	0·232060	0·721368	8·34982		88·41	4·258603	61
30	2·094395	75·96	0·636780	2·90732	0·243768	0·705186	8·16294		88·29	4·188790	60
31	2·164208	76·90	0·629296	3·03872	0·255795	0·688672	7·97234		88·16	4·118977	59
32	2·234021	77·78	0·621335	3·17432	0·268130	0·672025	7·78024		88·02	4·049164	58
33	2·303835	78·60	0·612956	3·31403	0·280769	0·655215	7·58630		87·87	3·979351	57
34	2·373648	79·36	0·603262	3·45831	0·293755	0·638423	7·39277		87·72	3·909538	56
35	2·443461	80·07	0·595149	3·60640	0·307028	0·621526	7·19787		87·56	3·839724	55
36	2·513274	80·73	0·585816	3·75846	0·320603	0·604601	7·00284		87·38	3·769911	54
37	2·583087	81·35	0·576251	3·91439	0·334475	0·587686	6·80799		87·19	3·700098	53
38	2·652900	81·93	0·566472	4·07408	0·348638	0·570774	6·61330		86·98	3·630285	52
39	2·722714	82·48	0·556538	4·23741	0·363085	0·553926	6·41945		86·76	3·560472	51
40	2·792527	82·99	0·546445	4·40422	0·377802	0·537146	6·22647		86·52	3·490659	50
41	2·862340	83·47	0·536223	4·57438	0·392784	0·520452	6·03465		86·26	3·420845	49
42	2·932153	83·91	0·525896	4·74775	0·408017	0·503894	5·84453		85·99	3·351032	48
43	3·001966	84·32	0·515480	4·92414	0·423489	0·487461	5·65601		85·70	3·281219	47
44	3·071779	84·70	0·505261	5·10338	0·439186	0·471192	5·46956		85·39	3·211406	46
45	3·141593	85·06	0·496266	5·28523	0·455091	0·455091	5·28523	0·496266	85·06	3·141593	45

ELLIPTIC FUNCTION TABLE. $\theta = 89^\circ{\cdot}71$; $\cos\theta = (\sqrt{2} - 1)^3 (2 - \sqrt{3})^2 = 0{\cdot}005107$.

$K = 3\sqrt{2}\,K' = 6{\cdot}664326$, $E = 1{\cdot}000218$, $E' = 1{\cdot}570772$, $\frac{1}{q} = e^{\frac{\pi}{3\sqrt{2}}} = 2{\cdot}097$.

r	F ϕ	ϕ	E (r)	D (r)	A (r)	B (r)	C (r)	F (r)	ϕ	F ψ	90—r
0	0·000000	0·00	0·000000	1 00000	0·000000	1·000000	13·99940	0·000000	90·00	6·664326	90
1	0·074048	4·24	0·062800	1·00233	0·005292	0·999589	13·99370		89·98	6·590278	89
2	0·148096	8·43	0·124799	1·00932	0·010600	0·998407	13·97640		89·96	6·516230	88
3	0·222144	12·63	0·185222	1 02099	0·015940	0·996302	13·94770		89·94	6·442182	87
4	0·296192	16·73	0·204437	1·03734	0·021327	0·993439	13·90760		89·91	6·368134	86
5	0·370240	20·74	0·298643	1·05838	0·026778	0·989768	13·85620		89·89	6·294086	85
6	0·444288	24·65	0·350513	1·08416	0 032308	0·985298	13·79370		89·86	6·220038	84
7	0·518336	28·45	0·398624	1·11467	0·037933	0·980042	13·72010		89·83	6·145990	83
8	0·592385	32·12	0·442705	1·14997	0·043669	0·974014	13·63570		89·81	6·071941	82
9	0·666433	35·64	0·482613	1·19008	0·049529	0·967224	13·54070		89·78	5·997893	81
10	0·740481	39·02	0·518304	1·23505	0·055530	0·959693	13·43530		89·75	5·923845	80
11	0·814529	42·23	0·549840	1·28490	0·061685	0·951437	13·31970		89·72	5·849797	79
12	0·888577	45·29	0·577340	1·33969	0·068010	0·942477	13·19430		89·69	5·775749	78
13	0·962625	48·20	0·600981	1·39946	0·074519	0·932832	13·05940		89·66	5·701701	77
14	1·036673	50·95	0·620993	1·46427	0·081225	0·922527	12·91510		89·63	5·627653	76
15	1·110721	53·55	0·639993	1·54407	0·088142	0·911585	12·76200		89·60	5·553605	75
16	1·184769	56·01	0·653294	1·62043	0·095281	0·900043	12·60080		89·56	5·479557	74
17	1·258817	58·32	0·663707	1·70215	0·102661	0·887894	12·43040		89·52	5·405509	73
18	1·332865	60·48	0·671560	1·78916	0·110287	0·875198	12·25280		89·48	5·331461	72
19	1·406913	62·49	0·675709	1·86545	0·118173	0·861975	12·06780		89·44	5·257413	71
20	1·480961	64·38	0·679400	1·96145	0·126330	0·848252	11·87570		89·39	5·183365	70
21	1·555009	66·15	0·681251	2·06282	0·134768	0 834061	11·67720		89·34	5·109317	69

90—r	F ψ	ψ	F (r)	C (r)	B (r)	A (r)	D (r)	E (r)	φ	F φ	r
22	1·629057	67·81	0·681457	2·16959	0·143498	0 819433	11·47250	Constant difference 0 0110538	89·28	5·035269	68
23	1·703106	69·36	0·680214	2·28180	0·152528	0·804397	11·26190		89·22	4·961220	67
24	1·777154	70·80	0·677696	2·39947	0 161867	0·788988	11·04660		89·16	4·887172	66
25	1·851202	72·15	0·674054	2·52264	0·171522	0·773236	10·82630		89·09	4·813124	65
26	1·925250	73·41	0·669430	2·65131	0·181499	0·757174	10 60156		89·02	4·739076	64
27	1·999298	74·58	0·664126	2·78549	0·191806	0·740836	10·37306		88·94	4·665028	63
28	2·073346	75·66	0·657722	2·92521	0·202447	0·724299	10·14114		88·86	4·590980	62
29	2·147394	76·68	0·650839	3·07044	0·213425	0·707440	9·90629		88·77	4·516932	61
30	2·221442	77·62	0·643386	3·22117	0·224745	0 690478	9·66892		88·67	4·442884	60
31	2·295490	78·50	0·635442	3·37738	0·236407	0·673352	9·42951		88·56	4·368836	59
32	2·369538	79·31	0·627073	3·53901	0·248414	0·656109	9·18852		88·45	4·294788	58
33	2·443586	80·07	0·618330	3·70604	0·260765	0·638778	8·94634		88·33	4·220740	57
34	2·517634	80·78	0·609255	3·87838	0·273458	0 621392	8·70345		88 20	4·146692	56
35	2·591682	81·44	0·599925	4·05597	0·286493	0·603976	8·46018		88·06	4·072644	55
36	2·665730	82·05	0·590340	4·23873	0·299865	0·586563	8·21703		87·91	3·998596	54
37	2·739778	82·61	0·580550	4·42654	0·313568	0·569180	7·97436		87·75	3·924548	53
38	2·813827	83·14	0·570578	4·61930	0·327599	0·551853	7·73258		87·57	3·850499	52
39	2·887875	83·63	0·560451	4·81684	0 342613	0·534608	7·49201		87·38	3·776451	51
40	2·961923	84 08	0·550188	5·01906	0·356609	0·517469	7·25305		87·18	3·702403	50
41	3·035971	84·50	0·539809	5·22577	0 371568	0·500458	7·01599		86·96	3·628355	49
42	3·110019	84·89	0·529332	5·43678	0 386818	0·483607	6·78128		86·73	3·554307	48
43	3·184067	85·26	0·518768	5·65192	0·402345	0·466927	6·54911		86·48	3·480259	47
44	3·258115	85·60	0·508126	5·87097	0·418135	0·450444	6·31982		86·21	3·406211	46
45	3·332163	85·92	0·497421	6·09368	0·434174	0·434174	6 09368	0·497421	85·92	3·332163	45

ELLIPTIC FUNCTION TABLE.

$$\theta = 89^\circ{\cdot}9,\ \sin 2\,\theta = (2 \sin 18^\circ)^{12},\ \cos\theta = \frac{(\sqrt{5}-1)^4\,(\sqrt[4]{5}-1)^4}{64\sqrt{2}},\ \cos(\theta - 45^\circ) = 3\,(\sqrt{5}-2).$$

$$K = 7{\cdot}8539814 = 5K', \qquad E = 1{\cdot}000075, \qquad E' = 1{\cdot}570784. \qquad \frac{1}{q} = e^{\frac{1}{5}\pi} = 1{\cdot}874456.$$

r	F (ϕ)	ϕ	E (r)	D (r)	A (r)	B (r)	C (r)	F (r)	ψ	F (ψ)	$90-r$
		°							°		
0	0·0000000	0·0	0·0000	1·0000	0·0000	1·0000	25·2752	0·0000	90·0	7·8539814	90
1	0·0872665	10·4	0·0756	1·0033	0 0034	0 9868	25·2185	Constant difference	90·0	7·7667149	89
2	0·1745329	13·5	0·1500	1·0133	0·0068	0·9854	25·1441		90·0	7·6794485	88
3	0·2617994	17·3	0·2218	1·0298	0 0103	0·9831	25·0519		90·0	7·5921820	87
4	0·3490658	21·5	0·2894	1·0531	0·0139	0·9798	24·9420		90·0	7·5049156	86
5	0·4363323	25·7	0·3537	1·0832	0·0175	0·9756	24·8143		90·0	7·4176491	85
6	0·5235988	29·9	0·4123	1·1200	0·0211	0·9706	24·6686		89·9	7·3303826	84
7	0·6108652	34·0	0·4654	1·1638	0·0249	0·9646	24·5047		89·9	7·2431162	83
8	0·6981317	37·9	0·5126	1·2146	0·0288	0·9578	24·3224		89·9	7·1558497	82
9	0·7853981	41·7	0·5540	1·2725	0·0328	0·9501	24·1216		89·9	7·0685833	81
10	0·8726646	45·3	0·5898	1·3377	0 0369	0·9415	23·9022		89·9	6·9813168	80
11	0·9599311	48·7	0·6203	1·4103	0·0412	0·9322	23·6640		89·9	6·8940503	79
12	1·0471975	51·8	0·6456	1·4904	0·0457	0·9221	23·4070		89·9	6·8067839	78
13	1·1344640	54·7	0·6664	1·5783	0·0504	0·9112	23·1311		89·9	6·7195174	77
14	1·2217304	57·5	0·6830	1·6740	0·0553	0·8996	22·8356		89·9	6·6322510	76
15	1·3089969	60·1	0·6958	1·7779	0·0604	0 8873	22·5245		89·9	6·5449845	75
16	1·3962634	62·5	0·7052	1·8900	0·0657	0·8744	22·1957		89·8	6·4577180	74
17	1·4835298	64·7	0·7110	2·0106	0·0713	0·8608	21·8507		89·8	6·3704516	73
18	1·5707963	66·7	0·7145	2·1398	0·0771	0·8466	21·4904		89·8	6·2831851	72
19	1·6580627	68·6	0·7176	2·2780	0·0833	0·8318	21·1163		89·8	6·1959187	71
20	1·7453292	70·3	0·7174	2·4252	0·0897	0 8165	20·7288		89·8	6·1086522	70
21	1·8325957	71·9	0·7156	2·5816	0·0964	0 8008	20·3289		89·7	6·0213857	69

90−r	F(ψ)	ψ	F(r)	C(r)	B(r)	A(r)	D(r)	E(r)	φ	F(φ)	r
22	1·9198621	73·4	0·7124	2·7477	0·1035	0·7846	19·9177		89·7	5·9341193	68
23	2·0071286	74·8	0·7078	2·9234	0·1109	0·7680	19·4961		89·7	5·8468528	67
24	2·0943950	76·0	0·7029	3·1090	0·1186	0·7510	19·0661		89·6	5·7595864	66
25	2·1816615	77·1	0·6962	3·3047	0·1267	0·7337	18·6261		89·6	5·6723199	65
26	2·2689280	78·2	0·6891	3·5106	0·1352	0·7161	18·1795		89·6	5·5850534	64
27	2·3561944	79·2	0·6814	3·7269	0·1440	0·6982	17·7267		89·5	5·4977870	63
28	2·4434609	80·1	0·6732	3·9539	0·1532	0·6802	17·2686		89·5	5·4105205	62
29	2·5307273	80·9	0·6645	4·1916	0·1629	0·6619	16·8061		89·4	5·3232541	61
30	2·6179938	81·7	0·6554	4·4401	0·1729	0·6436	16·3403		89·4	5·2359876	60
31	2·7052603	82·4	0·6458	4·6995	0·1833	0·6248	15·8644		89·3	5·1487211	59
32	2·7925267	83·0	0·6359	4·9700	0·1941	0·6047	15·3874		89·3	5·0614547	58
33	2·8797932	83·6	0·6258	5·2511	0·2054	0·5872	14·9103	Constant difference	89·2	4·9741882	57
34	2·9670596	84·1	0·6156	5·5443	0·2171	0·5684	14·4341		89·1	4·8869218	56
35	3·0543261	84·6	0·6052	5·8481	0·2292	0·5497	13·9595		89·1	4·7996553	55
36	3·1415926	85·1	0·5946	6·1630	0·2417	0·5311	13·4875		89·0	4·7123888	54
37	3·2288590	85·5	0·5840	6·4890	0·2546	0·5126	13·0190		88·9	4·6251224	53
38	3·3161255	85·9	0·5733	6·8259	0·2680	0·4943	12·5544		88·8	4·5378559	52
39	3·4033919	86·2	0·5625	7·1737	0·2818	0·4762	12·0949		88·7	4·4505895	51
40	3·4906584	86·5	0·5517	7·5321	0·2960	0·4583	11·6409		88·5	4·3633230	50
41	3·5779249	86·8	0·5409	7·9011	0·3106	0·4407	11·1931		88·4	4·2760565	49
42	3·6651913	87·1	0·5300	8·2802	0·3256	0·4223	10·7523		88·3	4·1887901	48
43	3·7524578	87·3	0·5191	8·6694	0·3410	0·4061	10·3188		88·1	4·1015236	47
44	3·8397242	87·5	0·5083	9·0682	0·3567	0·3893	9·8933		87·9	4·0142572	46
45	3·9269907	87·7	0·4990	9·4763	0·3729	0·3729	9·4763	0·4990	87·7	3·9269907	45

ELLIPTIC FUNCTION TABLE. $\theta = 89^\circ\ 56'$; $\sin 2\theta = \frac{1}{2}(\sqrt[3]{2} - 1)^4$, $\sin(\theta - 45^\circ) = \frac{1}{2}(3 - \sqrt[3]{4})$.

$K = 3\sqrt{3}\,K' = 8{\cdot}162093$, $E = 1{\cdot}000050$, $E' = 1{\cdot}570789$, $\frac{1}{q} = e^{\frac{\pi}{3}\sqrt{3}} = 1{\cdot}8305$.

r	F (ϕ)	ϕ	E (r)	D (r)	A (r)	B (r)	C (r)	F (r)	ψ	F (ψ)	90—r
		°							°		
0	0·000000	0·00	0·000000	1·00000	0·000000	1·000000	29·6038	0·000000	90·00	8·162093	90
1	0·090690	5·21	0·079330	1·00361	0·003070	0·999459	29·5888	Constant difference	89·99	8·071403	89
2	0·181380	10·33	0·157195	1·01444	0·006148	0·997985	29·5441		89·99	7·980713	88
3	0·272070	15·41	0·232320	1·03258	0·009268	0·995475	29·4698		89·98	7·890024	87
4	0·362760	20·34	0·303198	1·05796	0·012423	0·991970	29·3660		89·98	7·799334	86
5	0·453450	25·12	0·369175	1·09076	0·015649	0·987482	29·2332		89·97	7·708644	85
6	0·544140	29·73	0·429448	1·13103	0·018954	0·982025	29·0716		89·96	7·617954	84
7	0·634829	34·15	0·483591	1·17890	0·022355	0·975613	28·8819		89·96	7·527264	83
8	0·725519	38·35	0·531427	1·23448	0·025867	0·968268	28·6644		89·95	7·436574	82
9	0·816209	42·31	0·572972	1·29804	0·029513	0·960009	28·4199		89·94	7·345884	81
10	0·906899	46·03	0·608529	1·36944	0·033290	0·950863	28·1492		89·93	7·255194	80
11	0·997589	49·52	0·638358	1·44916	0·037232	0·940856	27·8529		89·92	7·164504	79
12	1·088279	52·77	0·662807	1·53687	0·041325	0·930016	27·5320		89·91	7·073814	78
13	1·178969	55·80	0·682682	1·63407	0·045655	0·918375	27·1874		89·90	6·983124	77
14	1·269659	58·62	0·698150	1·73972	0·050169	0·905966	26·8201		89·89	6·892434	76
15	1·360649	61·22	0·709807	1·85446	0·054905	0·892825	26·4310		89·88	6·801744	75
16	1·451039	63·62	0·718121	1·97855	0·057182	0·878986	26·0214		89·87	6·711055	74
17	1·541729	65·84	0·723522	2·11226	0·065101	0·864495	25·5924		89·86	6·620365	73
18	1·632419	67·88	0·726405	2·25584	0·070593	0·849383	25·1450		89·84	6·529675	72
19	1·723109	69·76	0·727125	2·40956	0·076367	0·833696	24·6806		89·82	6·438985	71
20	1·813799	71·48	0·725994	2·57371	0·082437	0·817473	24·2004		89·80	6·348295	70
21	1·904488	73·06	0·723286	2·74856	0·088817	0·800759	23·7056		89·78	6·257605	69

90−r	Γ(ψ)	ψ	F(r)	C(r)	B(r)	A(r)	D(r)	E(r)	φ	F(φ)	r
22	1·995178	74·51	0·719240	2·93440	0·095523	0·783597	23·1977	0·01111	89·76	6·166915	68
23	2·085868	75·84	0·714062	3·13146	0·102565	0·766030	22·6776		89·74	6·076225	67
24	2·176558	77·06	0·707926	3·34006	0·109959	0·748103	22·1470		89·72	5·985535	66
25	2·267248	78·17	0·700985	3·56043	0·117715	0·729859	21·6069		89·69	5·894845	65
26	2·357938	79·19	0·693366	3·79282	0·125846	0·711343	21·0588		89·66	5·804155	64
27	2·448628	80·12	0·685175	4·03752	0·134363	0·692598	20·5040		89·63	5·713465	63
28	2·539318	80·97	0·676509	4·29468	0·143275	0·673667	19·9436		89·59	5·622775	62
29	2·630008	81·75	0·667442	4·56454	0·152594	0·654594	19·3790		89·55	5·532085	61
30	2·720698	82·47	0·658038	4·84731	0·162327	0·635419	18·8115		89·51	5·441396	60
31	2·811388	83·12	0·648356	5·14308	0·172481	0·616186	18·2422		89·46	5·350706	59
32	2·902078	83·71	0·638433	5·45218	0·183064	0·596932	17·6724	Constant difference	89·41	5·260016	58
33	2·992768	84·25	0·628315	5·77455	0·194082	0·577697	17·1031		89·35	5·169326	57
34	3·083457	84·75	0·617993	6·11031	0·205538	0·558517	16·5355		89·29	5·078636	56
35	3·174147	85·20	0·607617	6·45950	0·217436	0·539430	15·9707		89·22	4·987946	55
36	3·264837	85·62	0·597085	6·82220	0 229778	0·520469	15·4096		89·15	4·897256	54
37	3·355527	86·00	0·586457	7·19834	0·242565	0·501669	14·8533		89·07	4·806566	53
38	3·446217	86·35	0·575748	7·58788	0·255794	0·483064	14·3027		88·98	4·715876	52
39	3·536907	86·68	0·564973	7·99070	0·269465	0·464670	13·7587		88·88	4·625186	51
40	3·627597	86·97	0·554143	8·40660	0·283571	0·446530	13·2220		88·77	4·534496	50
41	3·718287	87·23	0·543266	8·83558	0·298109	0·428664	12·6936		88·65	4·443806	49
42	3·808977	87·46	0·532350	9·27720	0·313070	0·411096	12·1740		88·52	4·353116	48
43	3·899667	87·68	0·521402	9·73126	0·328440	0·393849	11·6640		88·38	4·262427	47
44	3·990357	87·88	0·510426	10·19740	0·344227	0·376944	11·1643		88·23	4·171737	46
45	4·081047	88·06	0·499429	10·67520	0·360397	0·360397	10·6752	0 499429	88·06	4·081047	45

ELLIPTIC FUNCTION TABLE.

$$K = 7K' = 10{\cdot}99557, \quad E = 1, \quad \frac{1}{q} = e^{\frac{1}{7}\pi} = 1{\cdot}56643, \quad \sin 2\theta = \left(\frac{\sqrt{7}+1-\sqrt{2}\sqrt[4]{7}}{2\sqrt{2}}\right)^{12}, \quad \sqrt[4]{\kappa} + \sqrt[4]{\kappa'} = \sqrt[8]{2}.$$

r	F φ	φ	E (r)	D (r)	A (r)	B (r)	C (r)	I (r)	ψ	F ψ	90—r
0	0·000000	0·00	0·00000	1 00000	0·00000	1 00000	122	0 00000	90 00	10·99557	90
1											89
2											88
3											87
4											86
5											85
6											84
7											83
8											82
9											81
10											80
11								Constant difference			79
12											78
13											77
14											76
15											75
16											74
17											73
18											72
19											71
20											70
21											69

90−r	F ψ	ψ	F (r)	C (r)	B (r)	A (r)	D (r)	E (r)	φ	F φ	r
22											68
23											67
24											66
25											65
26											64
27											63
28											62
29											61
30			0·66666					0·33333			60
31											59
32											58
33											57
34											56
35											55
36											54
37			Constant difference					Constant difference			53
38											52
39											51
40											50
41											49
42											48
43											47
44											46
45	5·49778	89·4	0·49999	27	0·2650	0 2650	27	0·49999	89·4	5·49778	45

PART II. BESSEL FUNCTIONS.

See p. 115.

Part II. Bessel Functions.

Mr. Airey's Table.

Tables of the Neumann Functions $G_0(x)$ and $G_1(x)$ or Bessel Functions of the Second Kind.

Tables of the first solution $y = J_n(x)$ of Bessel's differential equation

$$\frac{d^2y}{dx^2} + \frac{1}{x} \cdot \frac{dy}{dx} + \left(1 - \frac{n^2}{x^2}\right) y = 0$$

when $n = 0$ and $n = 1$ have been calculated by Meissel[1] from the ascending series

$$J_0(x) = 1 - \frac{x^2}{2^2} + \frac{x^4}{2^2 \cdot 4^2} - \frac{x^6}{2^2 \cdot 4^2 \cdot 6^2} + \ldots$$

$$J_1(x) = \frac{x}{2} - \frac{x^3}{2^2 \cdot 4} + \frac{x^5}{2^2 \cdot 4^2 \cdot 6} - \ldots$$

to 12 places of decimals from $x = 0{\cdot}00$ to $x = 15{\cdot}50$ by the interval $0{\cdot}01$. For greater values of x than $15{\cdot}50$, these functions can be found from the semi-convergent expansions.

It is possible, however, to use these semi-convergent series to determine the values of $J_0(x)$, $J_1(x)$, etc., to 12 places of decimals[2] for values of x as small as 8.

Tables of the second solution[3] of Bessel's equation—viz.

$$Y_0(x),\ Y_1(x),\ G_0(x),\ G_1(x)\ .\ \text{etc.}—$$

are much less complete, and as these functions—Bessel functions of the second kind or Neumann functions, as they are sometimes called—are of considerable importance in their application to many physical problems, tables of $G_0(x)$ and $G_1(x)$ have been calculated to seven places of decimals.

Different writers have given different definitions of these second solutions.

The Neumann cylinder function[4] defined by

$$Y_0(x) = \frac{2}{\pi}\left[\left(\frac{x}{2}\right)^2 - (1 + \tfrac{1}{2})\frac{\left(\frac{x}{2}\right)^4}{2!^2} + \ldots - (\log 2 - \gamma - \log_e x)\, J_0(x)\right],$$

etc., differs from the $G_0(x)$ and $G_1(x)$ function only by the factor $\frac{\pi}{2}$.

[1] Gray and Mathews, *Treatise on Bessel Functions*, 1895.

[2] *Archiv. der Math. u. Physik.* III. Reihe, XX., 1913.

[3] B. A. Smith, *Messenger of Mathematics*, 26, 1897; Smith, *Phil. Mag.*, 45, 1898; Aldis, *Proc. Royal Society*, London, 64, 1898–9.

[4] Nielsen, *Theorie der Zylinderfunktionen*, p. 12.

On the other hand, the Neumann function[5] $Y_0(x)$, etc., defined by

$$Y_0(x) = J_0(x) \,.\, \log_e x + \left(\frac{x}{2}\right)^2 - (1+\tfrac{1}{2})\frac{\left(\frac{x}{2}\right)^4}{2!^2} + (1+\tfrac{1}{2}+\tfrac{1}{3})\frac{\left(\frac{x}{2}\right)^6}{3!^2} \;\ldots\; \text{etc.},$$

are found readily from $G_0(x)$, etc. by the relation

$$Y_n(x) = (\log 2 - \gamma)\, J_n(x) - G_n(x).$$

The following tables were calculated, with some slight corrections, from those already published,[6] by interpolation, first to fifths and then to halves.

The values for $x = 0{\cdot}01$ to $x = 0{\cdot}40$ were found from the ascending series,

$$-G_0(x) = \left(\frac{x}{2}\right)^2 - (1+\tfrac{1}{2})\frac{\left(\frac{x}{2}\right)^4}{2!^2} + \;\ldots\; - (\log 2 - \gamma - \log_e x)\, J_0(x), \text{ etc.}$$

To determine the value of $G_0(x)$ and $G_1(x)$ for intermediate values of the argument, interpolation formulæ may be used, such as

$$G_0(x \pm h) = \left[1 - \frac{h^2}{2} \ldots\right] G_0(x) + \left[\mp h + \frac{h^2}{2x}\right] G_1(x)$$

and

$$G_1(x \pm h) = \left[1 \mp \frac{h}{x} - \frac{h^2}{2}\left(1 - \frac{2}{x^2}\right) \ldots\right] G_1(x) + \left[\pm h - \frac{h^2}{2x} \ldots\right] G_0(x).$$

Neumann Functions or Bessel Functions of the Second Kind. $G_0(x)$ *and* $G_1(x)$.

x	$G_0(x)$	$G_1(x)$	x	$G_0(x)$	$G_1(x)$
0·01	+4·7209587	+100·0261051	0·20	+1·6981963	+5·2210521
0·02	+4·0274517	+50·0452769	0·21	+1·6471663	+4·9887552
0·03	+3·6214494	+33·3951624	0·22	+1·5983499	+4·7778488
0·04	+3·3330736	+25·0766778	0·23	+1·5515475	+4·5855201
0·05	+3·1090945	+20·0902576	0·24	+1·5065855	+4·4094258
0·06	+2·9258067	+16·7694905	0·25	+1·4633116	+4·2475986
0·07	+2·7705685	+14·4002597	0·26	+1·4215915	+4·0983739
0·08	+2·6358361	+12·6255419	0·27	+1·3813067	+3·9603349
0·09	+2·5167454	+11·2470137	0·28	+1·3423516	+3·8322673
0·10	+2·4099764	+10·1456966	0·29	+1·3046317	+3·7131248
0·11	+2·3131625	+9·2458884	0·30	+1·2680624	+3·6020011
0·12	+2·2245569	+8·4971288	0·31	+1·2325676	+3·4981072
0·13	+2·1428339	+7·8644903	0·32	+1·1980784	+3·4007530
0·14	+2·0669638	+7·3230293	0·33	+1·1645327	+3·3093323
0·15	+1·9961309	+6·8544580	0·34	+1·1318738	+3·2233107
0·16	+1·9296778	+6·4450632	0·35	+1·1000501	+3·1422149
0·17	+1·8670675	+6·0843612	0·36	+1·0690145	+3·0656245
0·18	+1·8078556	+5·7642001	0·37	+1·0387238	+2·9931649
0·19	+1·7516700	+5·4781456	0·38	+1·0091385	+2·9245007

[5] Gray and Mathews, *Bessel Functions*, p. 14.

[6] Report of the Mathematical Tables Committee: British Association, 1911, pp. 73–78.

Neumann Functions—continued.

x	$G_0(x)$	$G_1(x)$	x	$G_0(x)$	$G_1(x)$
0·39	+0·9802222	+2·8593316	0·97	−0·1011991	+1·2687378
0·40	+0·9519412	+2·7973873	0·98	−0·1138162	+1·2547216
0·41	+0·9242645	+2·7384238	0·99	−0·1262939	+1·2408530
0·42	+0·8971635	+2·6822210	1·00	−0·1386337	+1·2271262
0·43	+0·8706115	+2·6285790	1·01	−0·1508369	+1·2135361
0·44	+0·8445840	+2·5773161	1·02	−0·1629049	+1·2000774
0·45	+0·8190579	+2·5282673	1·03	−0·1748389	+1·1867454
0·46	+0·7940117	+2·4812818	1·04	−0·1866402	+1·1735355
0·47	+0·7694257	+2·4362218	1·05	−0·1983100	+1·1604432
0·48	+0·7452813	+2·3929611	1·06	−0·2098494	+1·1474643
0·49	+0·7215610	+2·3513837	1·07	−0·2212596	+1·1345946
0·50	+0·6982484	+2·3113834	1·08	−0·2325417	+1·1218304
0·51	+0·6753283	+2·2728620	1·09	−0·2436966	+1·1091679
0·52	+0·6527865	+2·2357292	1·10	−0·2547254	+1·0966036
0·53	+0·6306094	+2·1999014	1·11	−0·2656290	+1·0841341
0·54	+0·6087844	+2·1653015	1·12	−0·2764084	+1·0717560
0·55	+0·5872995	+2·1318578	1·13	−0·2870644	+1·0594664
0·56	+0·5661436	+2·0995041	1·14	−0·2975980	+1·0472622
0·57	+0·5453060	+2·0681786	1·15	−0·3080099	+1·0351405
0·58	+0·5247768	+2·0378241	1·16	−0·3183010	+1·0230987
0·59	+0·5045465	+2·0083871	1·17	−0·3284721	+1·0111340
0·60	+0·4846062	+1·9798181	1·18	−0·3385240	+0·9992441
0·61	+0·4649474	+1·9520705	1·19	−0·3484573	+0·9874264
0·62	+0·4455622	+1·9251008	1·20	−0·3582727	+0·9756787
0·63	+0·4264429	+1·8988685	1·21	−0·3679711	+0·9639989
0·64	+0·4075825	+1·8733358	1·22	−0·3775529	+0·9523848
0·65	+0·3889740	+1·8484670	1·23	−0·3870190	+0·9408343
0·66	+0·3706111	+1·8242286	1·24	−0·3963698	+0·9293456
0·67	+0·3524875	+1·8005894	1·25	−0·4056061	+0·9179169
0·68	+0·3345974	+1·7775199	1·26	−0·4147283	+0·9065463
0·69	+0·3169352	+1·7549924	1·27	−0·4237372	+0·8952321
0·70	+0·2994958	+1·7329808	1·28	−0·4326332	+0·8839729
0·71	+0·2822740	+1·7114606	1·29	−0·4414169	+0·8727670
0·72	+0·2652650	+1·6904087	1·30	−0·4500887	+0·8616128
0·73	+0·2484643	+1·6698031	1·31	−0·4586493	+0·8505091
0·74	+0·2318674	+1·6496233	1·32	−0·4670990	+0·8394545
0·75	+0·2154704	+1·6298497	1·33	−0·4754385	+0·8284477
0·76	+0·1992692	+1·6104640	1·34	−0·4836681	+0·8174875
0·77	+0·1832600	+1·5914488	1·35	−0·4917884	+0·8065726
0·78	+0·1674391	+1·5727875	1·36	−0·4997997	+0·7957021
0·79	+0·1518031	+1·5544646	1·37	−0·5077026	+0·7848748
0·80	+0·1363487	+1·5364653	1·38	−0·5154974	+0·7740897
0·81	+0·1210727	+1·5187754	1·39	−0·5231845	+0·7633458
0·82	+0·1059722	+1·5013818	1·40	−0·5307644	+0·7526423
0·83	+0·0910442	+1·4842717	1·41	−0·5382375	+0·7419783
0·84	+0·0762859	+1·4674332	1·42	−0·5456041	+0·7313528
0·85	+0·0616946	+1·4508548	1·43	−0·5528647	+0·7207651
0·86	+0·0472680	+1·4345258	1·44	−0·5600195	+0·7102146
0·87	+0·0330034	+1·4184358	1·45	−0·5670691	+0·6997004
0·88	+0·0188985	+1·4025749	1·46	−0·5740137	+0·6892220
0·89	+0·0049511	+1·3869340	1·47	−0·5808537	+0·6787786
0·90	−0·0088409	+1·3715040	1·48	−0·5875894	+0·6683696
0·91	−0·0224797	+1·3562765	1·49	−0·5942212	+0·6579946
0·92	−0·0359671	+1·3412435	1·50	−0·6007494	+0·6476529
0·93	−0·0493051	+1·3263972	1·51	−0·6071744	+0·6373441
0·94	−0·0624956	+1·3117303	1·52	−0·6134964	+0·6270677
0·95	−0·0755403	+1·2972359	1·53	−0·6197158	+0·6168232
0·96	−0·0884409	+1·2829072	1·54	−0·6258329	+0·6066102

Neumann Functions—continued.

x	$G_0(x)$	$G_1(x)$	x	$G_0(x)$	$G_1(x)$
1·55	−0·6318481	+0·5964284	2·13	−0·8161870	+0·0557487
1·56	−0·6377616	+0·5862773	2·14	−0·8167024	+0·0473427
1·57	−0·6435737	+0·5761566	2·15	−0·8171340	+0·0389723
1·58	−0·6492848	+0·5660661	2·16	−0·8174820	+0·0306376
1·59	−0·6548951	+0·5560054	2·17	−0·8177469	+0·0223391
1·60	−0.6604050	+0·5459743	2·18	−0·8179289	+0·0140769
1·61	−0·6658147	+0·5359725	2·19	−0·8180285	+0·0058514
1·62	−0·6711246	+0·5259999	2·20	−0·8180460	−0·0023370
1·63	−0·6763348	+0·5160561	2·21	−0·8179819	−0·0104881
1·64	−0·6814458	+0·5061411	2·22	−0·8178364	−0·0186016
1·65	−0·6864578	+0·4962547	2·23	−0·8176099	−0·0266772
1·66	−0·6913710	+0·4863967	2·24	−0·8173029	−0·0347145
1·67	−0·6961858	+0·4765671	2·25	−0·8169158	−0·0427132
1·68	−0·7009024	+0·4667656	2·26	−0·8164488	−0·0506730
1·69	−0·7055212	+0·4569922	2·27	−0·8159025	−0·0585936
1·70	−0·7100424	+0·4472469	2·28	−0·8152771	−0·0664747
1·71	−0·7144662	+0·4375296	2·29	−0·8145731	−0·0743159
1·72	−0·7187930	+0·4278403	2·30	−0·8137909	−0·0821170
1·73	−0·7230231	+0·4181789	2·31	−0·8129309	−0·0898776
1·74	−0·7271567	+0·4085454	2·32	−0·8119935	−0·0975974
1·75	−0·7311941	+0·3989398	2·33	−0·8109791	−0·1052760
1·76	−0·7351356	+0·3893622	2·34	−0·8098881	−0·1129132
1·77	−0·7389814	+0·3798125	2·35	−0·8087210	−0·1205086
1·78	−0·7427319	+0·3702909	2·36	−0·8074781	−0·1280619
1·79	−0·7463874	+0·3607974	2·37	−0·8061599	−0·1355728
1·80	−0·7499480	+0·3513320	2·38	−0·8047668	−0·1430409
1·81	−0·7534141	+0·3418948	2·39	−0·8032992	−0·1504660
1·82	−0·7567860	+0·3324859	2·40	−0·8017576	−0·1578477
1·83	−0·7600639	+0·3231054	2·41	−0·8001424	−0·1651857
1·84	−0·7632482	+0·3137534	2·42	−0·7984540	−0·1724796
1·85	−0·7663391	+0·3044301	2·43	−0·7966929	−0·1797292
1·86	−0·7693369	+0·2951355	2·44	−0·7948596	−0·1869341
1·87	−0·7722419	+0·2858699	2·45	−0·7929544	−0·1940940
1·88	−0·7750544	+0·2766333	2·46	−0·7909779	−0·2012086
1·89	−0·7777747	+0·2674260	2·47	−0·7889304	−0·2082776
1·90	−0·7804030	+0·2582480	2·48	−0·7868125	−0·2153006
1·91	−0·7829397	+0·2490996	2·49	−0·7846246	−0·2222774
1·92	−0·7853851	+0·2399809	2·50	−0·7823671	−0·2292077
1·93	−0·7877394	+0·2308921	2·51	−0·7800406	−0·2360911
1·94	−0·7900030	+0·2218335	2·52	−0·7776454	−0·2429272
1·95	−0·7921762	+0·2128052	2·53	−0·7751822	−0·2497159
1·96	−0·7942592	+0·2038074	2·54	−0·7726513	−0·2564567
1·97	−0·7962524	+0·1948404	2·55	−0·7700532	−0·2631493
1·98	−0·7981561	+0·1859044	2 56	−0·7673884	−0·2697937
1·99	−0·7999706	+0·1769996	2·57	−0·7646575	−0·2763893
2.00	−0·8016962	+0·1681262	2·58	−0·7618608	−0·2829359
2·01	−0·8033332	+0·1592844	2·59	−0·7589989	−0·2894332
2·02	−0·8048820	+0·1504746	2·60	−0·7560723	−0·2958808
2·03	−0·8063429	+0·1416970	2·61	−0·7530815	−0·3022785
2·04	−0·8077161	+0·1329518	2·62	−0·7500269	−0·3086260
2·05	−0·8090020	+0·1242393	2·63	−0·7469091	−0·3149230
2·06	−0·8102010	+0·1155598	2·64	−0·7437286	−0·3211692
2·07	−0·8113133	+0·1069134	2·65	−0·7404859	−0·3273644
2·08	−0·8123394	+0·0983006	2·66	−0·7371815	−0·3335082
2·09	−0·8132795	+0·0897216	2·67	−0·7338159	−0·3396004
2·10	−0·8141339	+0·0811766	2·68	−0·7303897	−0·3456406
2·11	−0·8149031	+0·0726659	2·69	−0·7269033	−0·3516286
2·12	−0·8155873	+0·0641898	2·70	−0·7233573	−0·3575642

Neumann Functions—continued.

x	$G_0(x)$	$G_1(x)$	x	$G_0(x)$	$G_1(x)$
2·71	−0·7197522	−0·3634471	3·29	−0·4287691	−0·6068260
2·72	−0·7160885	−0·3692769	3·30	−0·4226887	−0·6092380
2·73	−0·7123668	−0·3750535	3·31	−0·4165846	−0·6115874
2·74	−0·7085876	−0·3807765	3·32	−0·4104572	−0·6138742
2·75	−0·7047515	−0·3864457	3·33	−0·4043073	−0·6160985
2·76	−0·7008589	−0·3920609	3·34	−0·3981354	−0·6182601
2·77	−0·6969104	−0·3976218	3·35	−0·3919422	−0·6203590
2·78	−0·6929066	−0·4031281	3·36	−0·3857284	−0·6223953
2·79	−0·6888480	−0·4085796	3·37	−0·3794946	−0·6243689
2·80	−0·6847352	−0·4139761	3·38	−0·3732413	−0·6262797
2·81	−0·6805687	−0·4193173	3·39	−0·3669692	−0·6281279
2·82	−0·6763490	−0·4246030	3·40	−0·3606789	−0·6299133
2·83	−0·6720768	−0·4298329	3·41	−0·3543711	−0·6316361
2·84	−0·6677526	−0·4350067	3·42	−0·3480464	−0·6332962
2·85	−0·6633769	−0·4401244	3·43	−0·3417054	−0·6348936
2·86	−0·6589503	−0·4451856	3·44	−0·3353487	−0·6364283
2·87	−0·6544734	−0·4501901	3·45	−0·3289771	−0·6379004
2·88	−0·6499467	−0·4551378	3·46	−0·3225910	−0·6393099
2·89	−0·6453708	−0·4600284	3·47	−0·3161911	−0·6406568
2·90	−0·6407463	−0·4648616	3·48	−0·3097780	−0 6419411
2·91	−0·6360737	−0·4696373	3·49	−0·3033524	−0·6431630
2·92	−0·6313537	−0·4743552	3·50	−0·2969150	−0·6443225
2·93	−0·6265868	−0·4790153	3·51	−0·2904662	−0·6454196
2·94	−0·6217736	−0·4836172	3·52	−0·2840068	−0 6464542
2·95	−0·6169147	−0·4881608	3·53	−0·2775374	−0·6474266
2·96	−0·6120106	−0·4926458	3·54	−0·2710585	−0·6483368
2·97	−0·6070620	−0·4970722	3·55	−0·2645708	−0·6491849
2·98	−0·6020694	−0·5014397	3·56	−0·2580750	−0·6499709
2·99	−0·5970334	−0·5057482	3.57	−0·2515716	−0·6506949
3·00	−0·5919546	−0·5099974	3·58	−0·2450613	−0·6513570
3·01	−0·5868337	−0·5141872	3·59	−0·2385446	−0·6519573
3·02	−0·5816711	−0·5183175	3·60	−0·2320223	−0·6524959
3·03	−0·5764675	−0·5223880	3·61	−0·2254949	−0·6529728
3·04	−0·5712235	−0·5263987	3·62	−0·2189630	−0·6533882
3·05	−0·5659397	−0·5303493	3·63	−0·2124273	−0·6537422
3·06	−0·5606167	−0·5342397	3·64	−0·2058884	−0·6540349
3·07	−0·5552552	−0·5380698	3·65	−0·1993469	−0·6542664
3·08	−0·5498556	−0·5418394	3·66	−0·1928033	−0·6544369
3·09	−0·5444186	−0·5455484	3·67	−0·1862583	−0·6545464
3·10	−0·5389448	−0·5491967	3·68	−0·1797125	−0·6545951
3·11	−0·5334348	−0·5527841	3·69	−0·1731666	−0·6545831
3·12	−0·5278893	−0·5563105	3·70	−0·1666211	−0·6545106
3·13	−0·5223088	−0·5597758	3·71	−0·1600766	−0·6543777
3·14	−0·5166940	−0·5631798	3·72	−0·1535338	−0·6541845
3·15	−0·5110454	−0·5665225	3·73	−0·1469932	−0·6539312
3·16	−0·5053637	−0·5698037	3·74	−0·1404554	−0·6536181
3·17	−0·4996495	−0·5730233	3·75	−0·1339210	−0·6532452
3·18	−0·4939035	−0·5761813	3·76	−0·1273907	−0·6528126
3·19	−0·4881261	−0·5792776	3·77	−0·1208650	−0·6523206
3·20	−0·4823181	−0·5823120	3·78	−0·1143445	−0·6517694
3·21	−0·4764801	−0·5852845	3·79	−0·1078298	−0·6511590
3·22	−0·4706126	−0·5881950	3·80	−0·1013215	−0·6504898
3·23	−0·4647163	−0·5910433	3·81	−0·0948202	−0·6497619
3·24	−0·4587919	−0·5938295	3·82	−0·0883265	−0·6489755
3·25	−0·4528400	−0·5965535	3·83	−0·0818409	−0·6481308
3·26	−0·4468611	−0·5992152	3·84	−0·0753640	−0·6472279
3·27	−0·4408559	−0·6018146	3·85	−0·0688965	−0·6462671
3·28	−0·4348250	−0·6043515	3·86	−0·0624389	−0·6452486

Neumann Functions—continued.

x	$G_0(x)$	$G_1(x)$	x	$G_0(x)$	$G_1(x)$
3·87	−0·0559917	−0·6441727	4·45	+0·2816955	−0·4928942
3·88	−0·0495556	−0·6430395	4·46	+0·2866048	−0·4889507
3·89	−0·0431311	−0·6418493	4·47	+0·2914745	−0·4849697
3·90	−0·0367188	−0·6406022	4·48	+0·2963041	−0·4809515
3·91	−0·0303192	−0·6392986	4·49	+0·3010934	−0·4768966
3·92	−0·0239330	−0·6379386	4·50	+0·3058419	−0·4728055
3·93	−0·0175606	−0·6365225	4·51	+0·3105494	−0·4686786
3·94	−0·0112027	−0·6350506	4·52	+0·3152154	−0·4645163
3·95	−0·0048598	−0·6335231	4·53	+0·3198396	−0·4603190
3·96	+0·0014676	−0·6319402	4·54	+0·3244216	−0·4560873
3·97	+0·0077788	−0·6303022	4·55	+0·3289612	−0·4518215
3·98	+0·0140734	−0·6286093	4·56	+0·3334580	−0·4475222
3·99	+0·0203509	−0·6268619	4·57	+0·3379116	−0·4431897
4·00	+0·0266105	−0·6250602	4·58	+0·3423217	−0·4388246
4·01	+0·0328518	−0·6232045	4·59	+0·3466880	−0·4344272
4·02	+0·0390744	−0·6212950	4·60	+0·3510101	−0·4299980
4·03	+0·0452776	−0·6193321	4·61	+0·3552878	−0·4255376
4·04	+0·0514609	−0·6173160	4·62	+0·3595207	−0·4210463
4·05	+0·0576237	−0·6152470	4·63	+0·3637086	−0·4165246
4·06	+0·0637656	−0·6131254	4·64	+0·3678511	−0·4119730
4·07	+0·0698860	−0·6109515	4·65	+0·3719480	−0·4073920
4·08	+0·0759844	−0·6087255	4·66	+0·3759989	−0·4027820
4·09	+0·0820603	−0·6064479	4·67	+0·3800035	−0·3981435
4·10	+0·0881132	−0·6041189	4·68	+0·3839616	−0·3934770
4·11	+0·0941425	−0·6017388	4·69	+0·3878729	−0·3887829
4·12	+0·1001478	−0·5993080	4·70	+0·3917372	−0·3840617
4·13	+0·1061285	−0·5968267	4·71	+0·3955541	−0·3793140
4·14	+0·1120842	−0·5942953	4·72	+0·3993234	−0·3745401
4·15	+0·1180143	−0·5917141	4·73	+0·4030448	−0·3697406
4·16	+0·1239183	−0·5890835	4·74	+0·4067181	−0·3649160
4·17	+0·1297958	−0·5864038	4·75	+0·4103431	−0·3600667
4·18	+0·1356462	−0·5836752	4·76	+0·4139194	−0·3551933
4·19	+0·1414691	−0·5808982	4·77	+0·4174468	−0·3502961
4·20	+0·1472640	−0·5780732	4·78	+0·4209252	−0·3453757
4·21	+0·1530304	−0·5752004	4·79	+0·4243543	−0·3404327
4·22	+0·1587679	−0·5722801	4·80	+0·4277338	−0·3354674
4·23	+0·1644759	−0·5693129	4·81	+0·4310636	−0·3304804
4·24	+0·1701540	−0·5662990	4·82	+0·4343433	−0·3254721
4·25	+0·1758017	−0·5632387	4·83	+0·4375729	−0·3204432
4·26	+0·1814186	−0·5601325	4·84	+0·4407521	−0·3153940
4·27	+0·1870042	−0·5569807	4·85	+0·4438807	−0·3103250
4·28	+0·1925581	−0·5537837	4·86	+0·4469586	−0·3052368
4·29	+0·1980798	−0·5505419	4·87	+0·4499854	−0·3001299
4·30	+0·2035688	−0·5472556	4·88	+0·4529611	−0·2950047
4·31	+0·2090247	−0·5439253	4·89	+0·4558854	−0·2898618
4·32	+0·2144472	−0·5405513	4·90	+0·4587583	−0·2847016
4·33	+0·2198356	−0·5371340	4·91	+0·4615795	−0·2795247
4·34	+0·2251897	−0·5336737	4·92	+0·4643488	−0·2743316
4·35	+0·2305090	−0·5301709	4·93	+0·4670661	−0·2691228
4·36	+0·2357930	−0·5266261	4·94	+0·4697312	−0·2638987
4·37	+0·2410413	−0·5230395	4·95	+0·4723440	−0·2586599
4·38	+0·2462536	−0·5194116	4·96	+0·4749043	−0·2534069
4·39	+0·2514294	−0·5157428	4·97	+0·4774121	−0·2481402
4·40	+0·2565683	−0·5120335	4·98	+0·4798671	−0·2428603
4·41	+0·2616699	−0·5082841	4·99	+0·4822692	−0·2375677
4·42	+0·2667338	−0·5044951	5·00	+0·4846184	−0·2322629
4·43	+0·2717596	−0·5006668	5·01	+0·4869145	−0·2269464
4·44	+0·2767470	−0·4967997	5·02	+0·4891573	−0·2216188

Neumann Functions—continued.

x	$G_0(x)$	$G_1(x)$	x	$G_0(x)$	$G_1(x)$
5·03	+0·4913468	−0·2162805	5·61	+0·5259967	+0·0943309
5·04	+0·4934828	−0·2109321	5·62	+0·5250279	+0·0994135
5·05	+0·4955654	−0·2055740	5·63	+0·5240084	+0·1044775
5·06	+0·4975943	−0·2002068	5·64	+0·5229384	+0·1095224
5·07	+0·4995695	−0·1948310	5·65	+0·5218180	+0·1145478
5·08	+0·5014908	−0·1894470	5·66	+0·5206475	+0·1195532
5·09	+0·5033583	−0·1840555	5·67	+0·5194270	+0·1245381
5·10	+0·5051719	−0·1786568	5·68	+0·5181568	+0·1295023
5·11	+0·5069314	−0·1732515	5·69	+0·5168371	+0·1344452
5·12	+0·5086369	−0·1678402	5·70	+0·5154680	+0·1393663
5·13	+0·5102883	−0·1624233	5·71	+0·5140498	+0·1442653
5·14	+0·5118854	−0·1570014	5·72	+0·5125828	+0·1491418
5·15	+0·5134283	−0·1515749	5·73	+0·5110671	+0·1539954
5·16	+0·5149169	−0·1461444	5·74	+0·5095029	+0·1588255
5·17	+0·5163511	−0·1407103	5·75	+0·5078906	+0·1636319
5·18	+0·5177311	−0·1352732	5·76	+0·5062304	+0·1684141
5·19	+0·5190567	−0·1298336	5·77	+0·5045224	+0·1731716
5·20	+0·5203278	0·1243919	5·78	+0·5027670	+0·1779041
5·21	+0·5215445	−0·1189488	5·79	+0·5009644	+0·1826112
5·22	+0·5227068	−0·1135046	5·80	+0·4991149	+0·1872925
5·23	+0·5238146	−0·1080599	5·81	+0·4972187	+0·1919476
5·24	+0·5248680	−0·1026152	5·82	+0·4952760	+0·1965760
5·25	+0·5258669	−0·0971711	5·83	+0·4932872	+0·2011775
5·26	+0·5268114	−0·0917279	5·84	+0·4912526	+0·2057515
5·27	+0·5277015	−0·0862862	5·85	+0·4891723	+0·2102978
5·28	+0·5285371	−0·0808465	5·86	+0·4870467	+0·2148159
5·29	+0·5293184	−0·0754094	5·87	+0·4848761	+0·2193055
5·30	+0·5300453	−0·0699752	5·88	+0·4826607	+0·2237661
5·31	+0·5307179	−0·0645446	5·89	+0·4804009	+0·2281974
5·32	+0·5313362	−0·0591179	5·90	+0·4780969	+0·2325991
5·33	+0·5319003	−0·0536958	5·91	+0·4757490	+0·2369708
5·34	+0·5324101	−0·0482786	5·92	+0·4733576	+0·2413120
5·35	+0·5328658	−0·0428669	5·93	+0·4709229	+0·2456225
5·36	+0·5332675	−0·0374612	5·94	+0·4684453	+0·2499019
5·37	+0·5336151	−0·0320620	5·95	+0·4659250	+0·2541499
5·38	+0·5339088	−0·0266697	5·96	+0·4633624	+0·2583660
5·39	+0·5341486	−0·0212848	5·97	+0·4607578	+0·2625500
5·40	+0·5343345	−0·0159079	5·98	+0·4581115	+0·2667015
5·41	+0·5344667	−0·0105393	5·99	+0·4554239	+0·2708201
5·42	+0·5345453	0·0051797	6·00	+0·4526952	+0·2749056
5·43	+0·5345703	+0·0001705	6·01	+0·4499259	+0·2789576
5·44	+0·5345419	+0·0055109	6·02	+0·4471162	+0·2829757
5·45	+0·5344602	+0·0108409	6·03	+0·4442665	+0·2869596
5·46	+0·5343252	+0·0161601	6·04	+0·4413771	+0·2909091
5·47	+0·5341370	+0·0214680	6·05	+0·4384484	+0·2948238
5·48	+0·5338958	+0·0267642	6·06	+0·4354807	+0·2987034
5·49	+0·5336017	+0·0320482	6·07	+0·4324744	+0·3025475
5·50	+0·5332549	+0·0373194	6·08	+0·4294298	+0·3063559
5·51	+0·5328554	+0·0425774	6·09	+0·4263474	+0·3101283
5·52	+0·5324034	+0·0478218	6·10	+0·4232274	+0·3138643
5·53	+0·5318990	+0·0530520	6·11	+0·4200703	+0·3175637
5·54	+0·5313424	+0·0582677	6·12	+0·4168763	+0·3212261
5·55	+0·5307337	+0·0634683	6·13	+0·4136459	+0·3248514
5·56	+0·5300731	+0·0686535	6·14	+0·4103794	+0·3284391
5·57	+0·5293607	+0·0738227	6·15	+0·4070772	+0·3319890
5·58	+0·5285967	+0·0789755	6·16	+0·4037397	+0·3355009
5·59	+0·5277812	+0·0841115	6·17	+0·4003673	+0·3389745
5·60	+0·5269145	+0·0892301	6·18	+0·3969604	+0·3424094

Neumann Functions—continued.

x	$G_0(x)$	$G_1(x)$	x	$G_0(x)$	$G_1(x)$
6·19	+0·3935193	+0·3458055	6·77	+0·1498839	+0·4693276
6·20	+0·3900444	+0·3491624	6·78	+0·1451867	+0·4701097
6·21	+0·3865361	+0·3524799	6·79	+0·1404819	+0·4708447
6·22	+0·3829949	+0·3557578	6·80	+0·1357699	+0·4715325
6·23	+0·3794211	+0·3589958	6·81	+0·1310513	+0·4721732
6·24	+0·3758152	+0·3621937	6·82	+0·1263266	+0·4727668
6·25	+0·3721774	+0·3653512	6·83	+0·1215962	+0·4733133
6·26	+0·3685083	+0·3684681	6·84	+0·1168605	+0·4738128
6·27	+0·3648082	+0·3715441	6·85	+0·1121200	+0·4742652
6·28	+0·3610775	+0·3745790	6·86	+0·1073753	+0·4746705
6·29	+0·3573167	+0·3775726	6·87	+0·1026268	+0·4750288
6·30	+0·3535262	+0·3805247	6·88	+0·0978749	+0·4753401
6·31	+0·3497063	+0·3834350	6·89	+0·0931202	+0·4756045
6·32	+0·3458576	+0·3863034	6·90	+0·0883630	+0·4758220
6·33	+0·3419804	+0·3891296	6·91	+0·0836039	+0·4759926
6·34	+0·3380752	+0·3919135	6·92	+0·0788433	+0·4761164
6·35	+0·3341423	+0·3946547	6·93	+0·0740817	+0·4761934
6·36	+0·3301823	+0·3973532	6·94	+0·0693196	+0·4762237
6·37	+0·3261954	+0·4000087	6·95	+0·0645575	+0·4762074
6·38	+0·3221822	+0·4026211	6·96	+0·0597957	+0·4761445
6·39	+0·3181431	+0·4051902	6·97	+0·0550348	+0·4760351
6·40	+0·3140786	+0·4077157	6·98	+0·0502752	+0·4758793
6·41	+0·3099890	+0·4101975	6·99	+0·0455174	+0·4756771
6·42	+0·3058748	+0·4126355	7·00	+0·0407618	+0·4754286
6·43	+0·3017365	+0·4150295	7·01	+0·0360090	+0·4751339
6·44	+0·2975744	+0·4173793	7·02	+0·0312593	+0·4747932
6·45	+0·2933890	+0·4196848	7·03	+0·0265133	+0·4744065
6·46	+0·2891808	+0·4219457	7·04	+0·0217713	+0·4739738
6·47	+0·2849503	+0·4241620	7·05	+0·0170340	+0·4734954
6·48	+0·2806978	+0·4263334	7·06	+0·0123016	+0·4729713
6·49	+0·2764238	+0·4284600	7·07	+0·0075747	+0·4724016
6·50	+0·2721287	+0·4305415	7·08	+0·0028537	+0·4717865
6·51	+0·2678131	+0·4325778	7·09	−0·0018609	+0·4711260
6·52	+0·2634773	+0·4345687	7·10	−0·0065687	+0·4704203
6·53	+0·2591218	+0·4365142	7·11	−0·0112692	+0·4696695
6·54	+0·2547471	+0·4384142	7·12	−0·0159620	+0·4688738
6·55	+0·2503537	+0·4402685	7·13	−0·0206466	+0·4680333
6·56	+0·2459419	+0·4420769	7·14	−0·0253225	+0·4671481
6·57	+0·2415123	+0·4438395	7·15	−0·0299894	+0·4662183
6·58	+0·2370652	+0·4455560	7·16	−0·0346467	+0·4652442
6·59	+0·2326012	+0·4472265	7·17	−0·0392941	+0·4642259
6·60	+0·2281208	+0·4488507	7·18	−0·0439311	+0·4631635
6·61	+0·2236244	+0·4504287	7·19	−0·0485572	+0·4620572
6·62	+0·2191124	+0·4519603	7·20	−0·0531721	+0·4609071
6·63	+0·2145853	+0·4534455	7·21	−0·0577752	+0·4597135
6·64	+0·2100436	+0·4548841	7·22	−0·0623662	+0·4584764
6·65	+0·2054877	+0·4562762	7·23	−0·0669446	+0·4571962
6·66	+0·2009182	+0·4576216	7·24	−0·0715100	+0·4558729
6·67	+0·1963355	+0·4589203	7·25	−0·0760619	+0·4545067
6·68	+0·1917400	+0·4601723	7·26	−0·0806000	+0·4530979
6·69	+0·1871322	+0·4613774	7·27	−0·0851238	+0·4516466
6·70	+0·1825126	+0·4625356	7·28	−0·0896328	+0·4501530
6·71	+0·1778816	+0·4636469	7·29	−0·0941267	+0·4486173
6·72	+0·1732398	+0·4647113	7·30	−0·0986050	+0·4470397
6·73	+0·1685876	+0·4657287	7·31	−0·1030674	+0·4454205
6·74	+0·1639254	+0·4666990	7·32	−0·1075133	+0·4437598
6·75	+0·1592538	+0·4676223	7·33	−0·1119424	+0·4420578
6·76	+0·1545731	+0·4684985	7·34	−0·1163543	+0·4403148

Neumann Functions—continued.

x	$G_0(x)$	$G_1(x)$	x	$G_0(x)$	$G_1(x)$
7·35	−0·1207486	+0·4385310	7·93	−0·3328025	+0·2745266
7·36	−0·1251248	+0·4367067	7·94	−0·3355294	+0·2708413
7·37	−0·1294826	+0·4348420	7·95	−0·3382193	+0·2671340
7·38	−0·1338215	+0·4329371	7·96	−0·3408720	+0·2634050
7·39	−0·1381412	+0·4309923	7·97	−0·3434873	+0·2596548
7·40	−0·1424412	+0·4290079	7·98	−0·3460650	+0·2558838
7·41	−0·1467212	+0·4269841	7·99	−0·3486049	+0·2520923
7·42	−0·1509808	+0·4249211	8·00	−0·3511068	+0·2482808
7·43	−0·1552195	+0·4228192	8·01	−0·3535705	+0·2444496
7·44	−0·1594370	+0·4206787	8·02	−0·3559957	+0·2405992
7·45	−0·1636329	+0·4184997	8·03	−0·3583823	+0·2367298
7·46	−0·1678069	+0·4162826	8·04	−0·3607302	+0·2328420
7·47	−0·1719585	+0·4140277	8·05	−0·3630391	+0·2289361
7·48	−0·1760873	+0·4117351	8·06	−0·3653089	+0·2250126
7·49	−0·1801930	+0·4094051	8·07	−0·3675393	+0·2210718
7·50	−0·1842753	+0·4070381	8·08	−0·3697303	+0·2171141
7·51	−0·1883337	+0·4046343	8·09	−0·3718816	+0·2131399
7·52	−0·1923679	+0·4021940	8·10	−0·3739930	+0·2091497
7·53	−0·1963775	+0·3997174	8·11	−0·3760645	+0·2051438
7·54	−0·2003621	+0·3972049	8·12	−0·3780958	+0·2011227
7·55	−0·2043214	+0·3946567	8·13	−0·3800869	+0·1970867
7·56	−0·2082551	+0·3920731	8·14	−0·3820375	+0·1930362
7·57	−0·2121628	+0·3894544	8·15	−0·3839476	+0·1889717
7·58	−0·2160441	+0·3868010	8·16	−0·3858169	+0·1848937
7·59	0·2198987	+0·3841131	8·17	−0·3876454	+0·1808024
7·60	−0·2237262	+0·3813910	8·18	−0·3894329	+0·1766983
7·61	−0·2275264	+0·3786350	8·19	−0·3911793	+0·1725818
7·62	−0·2312988	+0·3758455	8·20	−0·3928845	+0·1684534
7·63	−0·2350431	+0·3730227	8·21	−0·3945483	+0·1643134
7·64	−0·2387591	+0·3701669	8·22	−0·3961707	+0·1601623
7·65	−0·2424464	+0·3672786	8·23	−0·3977515	+0·1560005
7·66	−0·2461046	+0·3643579	8·24	−0·3992907	+0·1518283
7·67	−0·2497334	+0·3614053	8·25	−0·4007881	+0·1476462
7·68	−0·2533326	+0·3584210	8·26	−0·4022436	+0·1434547
7·69	0·2569018	+0·3554054	8·27	−0·4036571	+0·1392542
7·70	−0·2604406	+0·3523587	8·28	−0·4050286	+0·1350450
7·71	−0·2639488	+0·3492814	8·29	−0·4063580	+0·1308276
7·72	−0·2674261	+0·3461738	8·30	−0·4076451	+0·1266023
7·73	−0·2708722	+0·3430362	8·31	−0·4088900	+0·1223697
7·74	−0·2742867	+0·3398689	8·32	−0·4100925	+0·1181301
7·75	−0·2776695	+0·3366724	8·33	−0·4112525	+0·1138840
7·76	−0·2810201	+0·3334469	8·34	−0·4123701	+0·1096318
7·77	−0·2843383	+0·3301927	8·35	−0·4134452	+0·1053738
7·78	−0·2876238	+0·3269103	8·36	−0·4144776	+0·1011106
7·79	−0·2908764	+0·3236000	8·37	−0·4154674	+0·0968425
7·80	−0·2940957	+0·3202621	8·38	−0·4164144	+0·0925700
7·81	−0·2972815	+0·3168970	8·39	−0·4173187	+0·0882935
7·82	−0·3004336	+0·3135051	8·40	−0·4181803	+0·0840133
7·83	−0·3035516	+0·3100867	8·41	−0·4189990	+0·0797299
7·84	−0·3066352	+0·3066421	8·42	−0·4197749	+0·0754438
7·85	−0·3096843	+0·3031718	8·43	−0·4205079	+0·0711554
7·86	−0·3126986	+0·2996761	8·44	−0·4211980	+0·0668650
7·87	−0·3156778	+0·2961554	8·45	−0·4218452	+0·0625731
7·88	−0·3186216	+0·2926101	8·46	−0·4224495	+0·0582801
7·89	−0·3215299	+0·2890405	8·47	−0·4230108	+0·0539864
7·90	−0·3244024	+0·2854469	8·48	−0·4235292	+0·0496925
7·91	−0·3272388	+0·2818298	8·49	−0·4240047	+0·0453988
7·92	−0·3300389	+0·2781896	8·50	−0·4244372	+0·0411056

Neumann Functions—continued.

x	$G_0(x)$	$G_1(x)$	x	$G_0'(x)$	$G_1(x)$
8·51	−0·4248268	+0·0368134	9·09	−0·3763619	−0·1966875
8·52	−0·4251735	+0·0325227	9·10	−0·3743773	−0·2002230
8·53	−0·4254772	+0·0282338	9·11	−0·3723575	−0·2037348
8·54	−0·4257381	+0·0239471	9·12	−0·3703027	−0·2072227
8·55	−0·4259562	+0·0196631	9·13	−0·3682131	−0·2106863
8·56	−0·4261314	+0·0153821	9·14	−0·3660890	−0·2141254
8·57	−0·4262638	+0·0111046	9·15	−0·3639307	−0·2175395
8·58	−0·4263535	+0·0068310	9·16	−0·3617383	−0·2209284
8·59	−0·4264004	+0·0025617	9·17	−0·3595122	−0·2242918
8·60	−0·4264047	−0·0017028	9·18	−0·3572525	−0·2276293
8·61	−0·4263663	−0·0059622	9·19	−0·3549596	−0·2309408
8·62	−0·4262854	−0·0102161	9·20	−0·3526338	−0·2342258
8·63	−0·4261620	−0·0144641	9·21	−0·3502752	−0·2374841
8·64	−0·4259961	−0·0187057	9·22	−0·3478842	−0·2407155
8·65	−0·4257879	−0·0229406	9·23	−0·3454611	−0·2439196
8·66	−0·4255373	−0·0271683	9·24	−0·3430059	−0·2470961
8·67	−0·4252445	−0·0313884	9·25	−0·3405192	−0·2502448
8·68	−0·4249096	−0·0356006	9·26	−0·3380011	−0·2533653
8·69	−0·4245325	−0·0398044	9·27	−0·3354519	−0·2564575
8·70	−0·4241135	−0·0439995	9·28	−0·3328720	−0·2595210
8·71	−0·4236526	−0·0481854	9·29	−0·3302616	−0·2625556
8·72	−0·4231498	−0·0523618	9·30	−0·3276210	−0·2655609
8·73	−0·4226054	−0·0565282	9·31	−0·3249505	−0·2685368
8·74	−0·4220193	−0·0606842	9·32	−0·3222504	−0·2714829
8·75	−0·4213917	−0·0648296	9·33	−0·3195210	−0·2743991
8·76	−0·4207228	−0·0689638	9·34	−0·3167625	−0·2772851
8·77	−0·4200125	−0·0730865	9·35	−0·3139754	−0·2801405
8·78	−0·4192611	−0 0771972	9·36	−0·3111598	−0·2829652
8·79	−0·4184687	−0·0812957	9·37	−0·3083161	−0·2857590
8·80	−0·4176353	−0·0853815	9·38	−0·3054447	−0·2885215
8·81	−0·4167611	−0·0894542	9·39	−0·3025458	−0·2912526
8·82	−0·4158463	−0·0935135	9·40	−0·2996198	−0·2939520
8·83	−0·4148909	−0·0975590	9·41	−0·2966669	−0·2966195
8·84	−0·4138952	−0·1015903	9·42	−0·2936875	−0·2992548
8·85	−0·4128593	−0·1056070	9·43	−0·2906819	−0·3018578
8·86	−0·4117832	−0·1096087	9·44	−0·2876505	−0·3044282
8·87	−0·4106671	−0·1135951	9·45	−0·2845935	−0·3069658
8·88	−0·4095113	−0·1175658	9·46	−0·2815113	−0·3094704
8·89	−0·4083159	−0·1215204	9·47	−0·2784042	−0·3119417
8·90	−0·4070810	−0·1254586	9·48	−0·2752726	−0·3143796
8·91	−0·4058068	−0·1293800	9·49	−0·2721167	−0·3167839
8·92	−0·4044935	−0·1332842	9·50	−0·2689370	−0·3191543
8·93	−0·4031412	−0·1371709	9·51	−0·2657337	−0·3214907
8·94	−0·4017501	−0·1410397	9·52	−0·2625073	−0·3237928
8·95	−0·4003205	−0·1448903	9·53	−0·2592580	−0·3260606
8·96	−0·3988524	−0·1487223	9·54	−0·2559862	−0·3282937
8·97	−0·3973461	−0·1525353	9·55	−0·2526923	−0·3304920
8·98	−0·3958017	−0·1563290	9·56	−0·2493765	−0·3326554
8·99	−0·3942195	−0·1601031	9·57	−0·2460393	−0·3347836
9·00	−0·3925997	−0·1638571	9·58	−0·2426810	−0·3368764
9·01	−0·3909424	−0·1675908	9·59	−0·2393019	−0·3389338
9·02	−0·3892479	−0·1713038	9·60	−0·2359024	−0·3409556
9·03	−0·3875164	−0·1749958	9·61	−0·2324829	−0·3429415
9·04	−0·3857481	−0·1786664	9·62	−0·2290437	−0·3448915
9·05	−0·3839431	−0·1823154	9·63	−0·2255852	−0·3468053
9·06	−0·3821018	−0·1859423	9·64	−0·2221077	−0·3486829
9·07	−0·3802244	−0·1895468	9·65	−0·2186117	−0·3505240
9·08	−0·3783110	−0·1931287	9·66	−0·2150974	−0·3523286

Neumann Functions—continued.

x	$G_0(x)$	$G_1(x)$	x	$G_0(x)$	$G_1(x)$
9·67	−0·2115653	−0·3540965	10·25	+0·0108311	−0·3910216
9·68	−0·2080156	−0·3558275	10·26	+0·0147388	−0·3905127
9·69	−0·2044488	−0·3575216	10·27	+0·0186412	−0·3899656
9·70	−0·2008653	−0·3591785	10·28	+0·0225380	−0·3893805
9·71	−0·1972654	−0·3607982	10·29	+0·0264287	−0·3887574
9·72	−0·1936495	−0·3623806	10·30	+0·0303130	−0·3880964
9·73	−0·1900179	−0·3639255	10·31	+0·0341905	−0·3873976
9·74	−0·1863711	−0·3654328	10·32	+0·0380608	−0·3866611
9·75	−0·1827094	−0·3669024	10·33	+0·0419236	−0·3858871
9·76	−0·1790332	−0·3683343	10·34	+0·0457784	−0·3850756
9·77	−0·1753428	−0·3697282	10·35	+0·0496249	−0·3842267
9·78	−0·1716387	−0·3710842	10·36	+0·0534628	−0·3833406
9·79	−0·1679212	−0·3724021	10·37	+0·0572916	−0·3824174
9·80	−0·1641908	−0·3736818	10·38	+0·0611110	−0·3814573
9·81	−0·1604478	−0·3749233	10·39	+0·0649206	−0·3804603
9·82	−0·1566925	−0·3761264	10·40	+0·0687201	−0·3794266
9·83	−0·1529254	−0·3772911	10·41	+0·0725090	−0·3783563
9·84	−0·1491468	−0·3784172	10·42	+0·0762871	−0·3772496
9·85	−0·1453571	−0·3795048	10·43	+0·0800539	−0·3761066
9·86	−0·1415568	−0·3805538	10·44	+0·0838091	−0·3749274
9·87	−0·1377462	−0·3815640	10·45	+0·0875523	−0·3737122
9·88	−0·1339256	−0·3825355	10·46	+0·0912832	−0·3724612
9·89	−0·1300956	−0·3834682	10·47	+0·0950014	−0·3711745
9·90	−0·1262564	−0·3843620	10·48	+0·0987066	−0·3698522
9·91	−0·1224085	−0·3852168	10·49	+0·1023984	−0·3684946
9·92	−0·1185522	−0·3860327	10·50	+0·1060764	−0·3671018
9·93	−0·1146879	−0·3868096	10·51	+0·1097403	−0·3656739
9·94	0·1108161	−0·3875474	10·52	+0·1133898	−0·3642112
9·95	−0·1069371	−0·3882462	10·53	+0·1170244	−0·3627138
9·96	−0·1030513	−0·3889058	10·54	+0·1206439	−0·3611819
9·97	−0·0991591	−0·3895263	10·55	+0·1242479	−0·3596157
9·98	−0·0952609	−0·3901076	10·56	+0·1278361	−0·3580153
9·99	−0·0913571	−0·3906497	10·57	+0·1314081	−0·3563810
10·00	−0·0874480	−0·3911526	10·58	+0·1349636	−0·3547129
10·01	−0·0835341	−0·3916163	10·59	+0·1385022	−0·3530112
10·02	−0·0796158	−0·3920408	10·60	+0·1420237	−0·3512762
10·03	−0·0756934	−0·3924261	10·61	+0·1455276	−0·3495080
10·04	−0·0717674	−0·3927722	10·62	+0·1490137	−0·3477069
10·05	−0·0678381	−0·3930791	10·63	+0·1524817	−0·3458730
10·06	−0·0639059	−0·3933467	10·64	+0·1559311	−0·3440066
10·07	−0·0599713	−0·3935751	10·65	+0·1593617	−0·3421079
10·08	−0·0560346	−0·3937644	10·66	+0·1627731	−0·3401770
10·09	−0·0520962	−0·3939145	10·67	+0·1661651	−0·3382142
10·10	−0·0481564	−0·3940255	10·68	+0·1695373	−0·3362198
10·11	−0·0442158	−0·3940974	10·69	+0·1728894	−0·3341939
10·12	−0·0402746	−0·3941302	10·70	+0·1762211	−0·3321368
10·13	−0·0363333	−0·3941240	10·71	+0·1795321	−0·3300487
10·14	−0·0323922	−0·3940787	10·72	+0·1828220	−0·3279299
10·15	−0·0284518	−0·3939945	10·73	+0·1860906	−0·3257805
10·16	−0·0245125	−0·3938714	10·74	+0·1893375	−0·3236009
10·17	−0·0205746	−0·3937094	10·75	+0·1925625	−0·3213912
10·18	−0·0166384	−0·3935086	10·76	+0·1957653	−0·3191518
10·19	−0·0127045	−0·3932690	10·77	+0·1989455	−0·3168828
10·20	−0·0087732	−0·3929908	10·78	+0·2021028	−0·3145845
10·21	−0·0048449	−0·3926739	10·79	+0·2052371	−0·3122571
10·22	−0·0009199	−0·3923185	10·80	+0·2083479	−0·3099010
10·23	+0·0030014	−0·3919246	10·81	+0·2114350	−0·3075163
10·24	+0·0069185	−0·3914923	10·82	+0·2144981	−0·3051034

Neumann Functions—continued.

x	$G_0(x)$	$G_1(x)$	x	$G_0(x)$	$G_1(x)$
10·83	+0·2175370	−0·3026625	11·41	+0·3441456	−0·1232874
10·84	+0·2205513	−0·3001938	11·42	+0·3453607	−0·1197334
10·85	+0·2235408	−0·2976977	11·43	+0·3465402	−0·1161706
10·86	+0·2265051	−0·2951743	11·44	+0·3476841	−0·1125994
10·87	+0·2294441	−0·2926240	11·45	+0·3487922	−0·1090202
10·88	+0·2323575	−0·2900471	11·46	+0·3498644	−0·1054333
10·89	+0·2352450	−0·2874438	11·47	+0·3509007	−0·1018390
10·90	+0·2381063	−0·2848144	11·48	+0·3519011	−0·0982378
10·91	+0·2409412	−0·2821592	11·49	+0·3528655	−0·0946300
10·92	+0·2437494	−0·2794784	11·50	+0·3537937	−0·0910159
10·93	+0·2465307	−0·2767724	11·51	+0·3546858	−0·0873959
10·94	+0·2492848	−0·2740415	11·52	+0·3555416	−0·0837704
10·95	+0·2520114	−0·2712859	11·53	+0·3563611	−0·0801398
10·96	+0·2547104	−0·2685059	11·54	+0·3571443	−0·0765043
10·97	+0·2573815	−0·2657018	11·55	+0·3578912	−0·0728644
10·98	+0·2600244	−0·2628740	11·56	+0·3586016	−0·0692204
10·99	+0·2626389	−0·2600226	11·57	+0·3592755	−0·0655727
11·00	+0·2652248	−0·2571481	11·58	+0·3599130	−0·0619217
11·01	+0·2677818	−0·2542507	11·59	+0·3605140	−0·0582677
11·02	+0·2703097	−0·2513307	11·60	+0·3610784	−0·0546110
11·03	+0·2728083	−0·2483884	11·61	+0·3616062	−0·0509521
11·04	+0·2752774	−0·2454242	11·62	+0·3620974	−0·0472912
11·05	+0·2777167	−0·2424384	11·63	+0·3625520	−0·0436288
11·06	+0·2801261	−0·2394312	11·64	+0·3629700	−0·0399653
11·07	+0·2825053	−0·2364030	11·65	+0·3633514	−0·0363009
11·08	+0·2848541	−0·2333541	11·66	+0·3636961	−0·0326360
11·09	+0·2871723	−0·2302848	11·67	+0·3640041	−0·0289711
11·10	+0·2894597	−0·2271954	11·68	+0·3642755	−0·0253064
11·11	+0·2917161	−0·2240863	11·69	+0·3645103	−0·0216424
11·12	+0·2939413	−0·2209578	11·70	+0·3647084	−0·0179793
11·13	+0·2961352	−0·2178102	11·71	+0·3648699	−0·0143176
11·14	+0·2982975	−0·2146438	11·72	+0·3649948	−0·0106576
11·15	+0·3004280	−0·2114590	11·73	+0·3650831	−0·0069996
11·16	+0·3025266	−0·2082561	11·74	+0·3651348	−0·0033441
11·17	+0·3045931	−0·2050354	11·75	+0·3651500	+0·0003087
11·18	+0·3066272	−0·2017972	11·76	+0·3651286	+0·0039583
11·19	+0·3086289	−0·1985419	11·77	+0·3650708	+0·0076044
11·20	+0·3105980	−0·1952699	11·78	+0·3649766	+0·0112467
11·21	+0·3125343	−0·1919814	11·79	+0·3648459	+0·0148847
11·22	+0·3144376	−0·1886768	11·80	+0·3646789	+0·0185182
11·23	+0·3163078	−0·1853565	11·81	+0·3644756	+0·0221468
11·24	+0·3181447	−0·1820207	11·82	+0·3642360	+0·0257701
11·25	+0·3199481	−0·1786698	11·83	+0·3639602	+0·0293878
11·26	+0·3217180	−0·1753042	11·84	+0·3636483	+0·0329995
11·27	+0·3234542	−0·1719242	11·85	+0·3633003	+0·0366049
11·28	+0·3251565	−0·1685301	11·86	+0·3629162	+0·0402036
11·29	+0·3268248	−0·1651223	11·87	+0·3624962	+0·0437953
11·30	+0·3284589	−0·1617012	11·88	+0·3620403	+0·0473796
11·31	+0·3300588	−0·1582671	11·89	+0·3615486	+0·0509562
11·32	+0·3316242	−0·1548203	11·90	+0·3610212	+0·0545247
11·33	+0·3331551	−0·1513612	11·91	+0·3604581	+0·0580848
11·34	+0·3346514	−0·1478901	11·92	+0·3598595	+0·0616362
11·35	+0·3361129	−0·1444074	11·93	+0·3592254	+0·0651785
11·36	+0·3375395	−0·1409135	11·94	+0·3585560	+0·0687113
11·37	+0·3389312	−0·1374087	11·95	+0·3578512	+0·0722344
11·38	+0·3402877	−0·1338933	11·96	+0·3571113	+0·0757474
11·39	+0·3416090	−0·1303677	11·97	+0·3563363	+0·0792499
11·40	+0·3428950	−0·1268323	11·98	+0·3555263	+0·0827416

Neumann Functions—continued.

x	$G_0(x)$	$G_1(x)$	x	$G_0(x)$	$G_1(x)$
11·99	+0·3546815	+0·0862222	12·57	+0·2514309	+0·2584717
12·00	+0·3538019	+0·0896913	12·58	+0·2488347	+0·2607666
12·01	+0·3528877	+0·0931486	12·59	+0·2462157	+0·2630338
12·02	+0·3519389	+0·0965938	12·60	+0·2435741	+0·2652730
12·03	+0·3509558	+0·1000266	12·61	+0·2409103	+0·2674841
12·04	+0·3499384	+0·1034466	12·62	+0·2382245	+0·2696669
12·05	+0·3488869	+0·1068535	12·63	+0·2355170	+0·2718212
12·06	+0·3478014	+0·1102469	12·64	+0·2327882	+0·2739467
12·07	+0·3466820	+0·1136265	12·65	+0·2300382	+0·2760433
12·08	+0·3455289	+0·1169921	12·66	+0·2272674	+0·2781109
12·09	+0·3443422	+0·1203433	12·67	+0·2244761	+0·2801492
12·10	+0·3431221	+0·1236798	12·68	+0·2216645	+0·2821581
12·11	+0·3418687	+0·1270012	12·69	+0·2188330	+0·2841374
12·12	+0·3405821	+0·1303073	12·70	+0·2159819	+0·2860869
12·13	+0·3392626	+0·1335977	12·71	+0·2131114	+0·2880065
12·14	+0·3379103	+0·1368722	12·72	+0·2102219	+0·2898959
12·15	+0·3365252	+0·1401304	12·73	+0·2073136	+0·2917550
12·16	+0·3351077	+0·1433719	12·74	+0·2043869	+0·2935837
12·17	+0·3336579	+0·1465965	12·75	+0·2014421	+0·2953818
12·18	+0·3321759	+0·1498040	12·76	+0·1984794	+0·2971491
12·19	+0·3306619	+0·1529940	12·77	+0·1954992	+0·2988856
12·20	+0·3291161	+0·1561661	12·78	+0·1925018	+0·3005910
12·21	+0·3275387	+0·1593202	12·79	+0·1894875	+0·3022652
12·22	+0·3259298	+0·1624558	12·80	+0·1864566	+0·3039080
12·23	+0·3242896	+0·1655727	12·81	+0·1834094	+0·3055194
12·24	+0·3226184	+0·1686706	12·82	+0·1803463	+0·3070991
12·25	+0·3209163	+0·1717493	12·83	+0·1772676	+0·3086471
12·26	+0·3191835	+0·1748084	12·84	+0·1741735	+0·3101633
12·27	+0·3174202	+0·1778477	12·85	+0·1710644	+0·3116474
12·28	+0·3156266	+0·1808668	12·86	+0·1679406	+0·3130994
12·29	+0·3138029	+0·1838655	12·87	+0·1648025	+0·3145192
12·30	+0·3119493	+0·1868435	12·88	+0·1616503	+0·3159066
12·31	+0·3100660	+0·1898006	12·89	+0·1584844	+0·3172616
12·32	+0·3081533	+0·1927364	12·90	+0·1553052	+0·3185840
12·33	+0·3062114	+0·1956507	12·91	+0·1521129	+0·3198737
12·34	+0·3042404	+0·1985432	12·92	+0·1489078	+0·3211307
12·35	+0·3022406	+0·2014136	12·93	+0·1456903	+0·3223547
12·36	+0·3002121	+0·2042617	12·94	+0·1424608	+0·3235458
12·37	+0·2981553	+0·2070873	12·95	+0·1392196	+0·3247038
12·38	+0·2960704	+0·2098900	12·96	+0·1359669	+0·3258287
12·39	+0·2939576	+0·2126696	12·97	+0·1327031	+0·3269204
12·40	+0·2918171	+0·2154258	12·98	+0·1294286	+0·3279787
12·41	+0·2896492	+0·2181584	12·99	+0·1261436	+0·3290036
12·42	+0·2874540	+0·2208672	13·00	+0·1228486	+0·3299950
12·43	+0·2852319	+0·2235518	13·01	+0·1195439	+0·3309529
12·44	+0·2829831	+0·2262121	13·02	+0·1162297	+0·3318771
12·45	+0·2807078	+0·2288478	13·03	+0·1129064	+0·3327677
12·46	+0·2784063	+0·2314586	13·04	+0·1095744	+0·3336245
12·47	+0·2760788	+0·2340443	13·05	+0·1062340	+0·3344475
12·48	+0·2737255	+0·2366047	13·06	+0·1028856	+0·3352366
12·49	+0·2713467	+0·2391396	13·07	+0·0995294	+0·3359918
12·50	+0·2689428	+0·2416487	13·08	+0·0961659	+0·3367131
12·51	+0·2665139	+0·2441318	13·09	+0·0927953	+0·3374003
12·52	+0·2640603	+0·2465886	13·10	+0·0894180	+0·3380535
12·53	+0·2615822	+0·2490190	13·11	+0·0860344	+0·3386726
12·54	+0·2590800	+0·2514228	13·12	+0·0826447	+0·3392575
12·55	+0·2565539	+0·2537996	13·13	+0·0792493	+0·3398083
12·56	+0·2540041	+0·2561493	13·14	+0·0758486	+0·3403249

Neumann Functions—continued.

x	$G_0(x)$	$G_1(x)$	x	$G_0(x)$	$G_1(x)$
13·15	+0·0724429	+0·3408073	13·73	−0·1220050	+0·3111202
13·16	+0·0690326	+0·3412554	13·74	−0·1251089	+0·3096586
13·17	+0·0656180	+0·3416692	13·75	−0·1281981	+0·3081673
13·18	+0·0621994	+0·3420488	13·76	−0·1312722	+0·3066465
13·19	+0·0587771	+0·3423941	13·77	−0·1343310	+0·3050963
13·20	+0·0553516	+0·3427052	13·78	−0·1373741	+0·3035168
13·21	+0·0519232	+0·3429820	13·79	−0·1404013	+0·3019083
13·22	+0·0484921	+0·3432244	13·80	−0·1434122	+0·3002710
13·23	+0·0450588	+0·3434325	13·81	−0·1464066	+0·2986050
13·24	+0·0416235	+0·3436064	13·82	−0·1493842	+0·2969105
13·25	+0·0381867	+0·3437460	13·83	−0·1523447	+0·2951877
13·26	+0·0347487	+0·3438513	13·84	−0·1552879	+0·2934368
13·27	+0·0313098	+0·3439224	13·85	−0·1582134	+0·2916580
13·28	+0·0278703	+0·3439592	13·86	−0·1611210	+0·2898514
13·29	+0·0244306	+0·3439618	13·87	−0·1640103	+0·2880174
13·30	+0·0209912	+0·3439302	13·88	−0·1668812	+0·2861560
13·31	+0·0175522	+0·3438645	13·89	−0·1697334	+0·2842675
13·32	+0·0141140	+0·3437646	13·90	−0·1725665	+0·2823521
13·33	+0·0106770	+0·3436306	13·91	−0·1753803	+0·2804100
13·34	+0·0072415	+0·3434625	13·92	−0·1781746	+0·2784414
13·35	+0·0038078	+0·3432604	13·93	−0·1809491	+0·2764465
13·36	+0·0003764	+0·3430244	13·94	−0·1837035	+0·2744256
13·37	−0·0030525	+0·3427544	13·95	−0·1864375	+0·2723788
13·38	−0·0064786	+0·3424506	13·96	−0·1891509	+0·2703064
13·39	−0·0099014	+0·3421130	13·97	−0·1918435	+0·2682086
13·40	−0·0133207	+0·3417416	13·98	−0·1945150	+0·2660856
13·41	−0·0167361	+0·3413365	13·99	−0·1971652	+0·2639377
13·42	−0·0201473	+0·3408978	14·00	−0·1997937	+0·2617651
13·43	−0·0235539	+0·3404255	14·01	−0·2024004	+0·2595680
13·44	−0·0269557	+0·3399197	14·02	−0·2049850	+0·2573466
13·45	−0·0303522	+0·3393805	14·03	−0·2075472	+0·2551012
13·46	−0·0337432	+0·3388080	14·04	−0·2100869	+0·2528321
13·47	−0·0371283	+0·3382022	14·05	−0·2126038	+0·2505395
13·48	−0·0405072	+0·3375633	14·06	−0·2150976	+0·2482235
13·49	−0·0438795	+0·3368913	14·07	−0·2175682	+0·2458845
13·50	−0·0472449	+0·3361863	14·08	−0·2200152	+0·2435227
13·51	−0·0506031	+0·3354484	14·09	−0·2224385	+0·2411383
13·52	−0·0539538	+0·3346777	14·10	−0·2248379	+0·2387317
13·53	−0·0572966	+0·3338743	14·11	−0·2272131	+0·2363030
13·54	−0·0606311	+0·3330383	14·12	−0·2295639	+0·2338526
13·55	−0·0639572	+0·3321698	14·13	−0·2318901	+0·2313806
13·56	−0·0672744	+0·3312689	14·14	−0·2341914	+0·2288874
13·57	−0·0705824	+0·3303358	14·15	−0·2364677	+0·2263732
13·58	−0·0738810	+0·3293705	14·16	−0·2387188	+0·2238382
13·59	−0·0771697	+0·3283732	14·17	−0·2409444	+0·2212828
13·60	−0·0804483	+0·3273439	14·18	−0·2431444	+0·2187071
13·61	−0·0837164	+0·3262828	14·19	−0·2453185	+0·2161115
13·62	−0·0869738	+0·3251901	14·20	−0·2474666	+0·2134962
13·63	−0·0902201	+0·3240658	14·21	−0·2495884	+0·2108615
13·64	−0·0934550	+0·3229102	14·22	−0·2516838	+0·2082077
13·65	−0·0966782	+0·3217233	14·23	−0·2537525	+0·2055351
13·66	−0·0998894	+0·3205053	14·24	−0·2557944	+0·2028439
13·67	−0·1030882	+0·3192563	14·25	−0·2578093	+0·2001344
13·68	−0·1062744	+0·3179765	14·26	−0·2597970	+0·1974069
13·69	−0·1094476	+0·3166660	14·27	−0·2617574	+0·1946617
13·70	−0·1126076	+0·3153249	14·28	−0·2636902	+0·1918990
13·71	−0·1157540	+0·3139535	14·29	−0·2655953	+0·1891192
13·72	−0·1188866	+0·3125519	14·30	−0·2674725	+0·1863225

Neumann Functions—continued.

x	$G_0(x)$	$G_1(x)$	x	$G_0(x)$	$G_1(x)$
14·31	−0·2693217	+0·1835092	14·89	−0·3244344	+0·0024150
14·32	−0·2711426	+0·1806797	14·90	−0·3244423	−0·0008299
14·33	−0·2729352	+0·1778342	14·91	−0·3244178	−0·0040726
14·34	−0·2746992	+0·1749729	14·92	−0·3243608	−0·0073127
14·35	−0·2764346	+0·1720962	14·93	−0·3242715	−0·0105499
14·36	−0·2781411	+0·1692044	14·94	−0·3241498	−0·0137839
14·37	−0·2798186	+0·1662978	14·95	−0·3239958	−0·0170143
14·38	−0·2814669	+0·1633767	14·96	−0·3238096	−0·0202409
14·39	−0·2830860	+0·1604414	14·97	−0·3235911	−0·0234633
14·40	−0·2846757	+0·1574921	14·98	−0·3233403	−0·0266812
14·41	−0·2862358	+0·1545292	14·99	−0·3230574	−0·0298944
14·42	−0·2877662	+0·1515530	15·00	−0·3227425	−0·0331024
14·43	−0·2892668	+0·1485638	15·01	−0·3223955	−0·0363050
14·44	−0·2907374	+0·1455619	15·02	−0·3220164	−0·0395018
14·45	−0·2921780	+0·1425476	15·03	−0·3216054	−0·0426926
14·46	−0·2935884	+0·1395211	15·04	−0·3211626	−0·0458770
14·47	−0·2949684	+0·1364829	15·05	−0·3206880	−0·0490547
14·48	−0·2963180	+0·1334332	15·06	−0·3201816	−0·0522255
14·49	−0·2976370	+0·1303723	15·07	−0·3196435	−0·0553890
14·50	−0·2989254	+0·1273006	15·08	−0·3190738	−0·0585448
14·51	−0·3001830	+0·1242183	15·09	−0·3184726	−0·0616927
14·52	−0·3014098	+0·1211258	15·10	−0·3178400	−0·0648324
14·53	−0·3026056	+0·1180234	15·11	−0·3171760	−0·0679636
14·54	−0·3037702	+0·1149113	15·12	−0·3164808	−0·0710859
14·55	−0·3049037	+0·1117900	15·13	−0·3157544	−0·0741991
14·56	−0·3060060	+0·1086597	15·14	−0·3149968	−0·0773028
14·57	−0·3070769	+0·1055207	15·15	−0·3142083	−0·0803968
14·58	−0·3081164	+0·1023734	15·16	−0·3133889	−0·0834807
14·59	−0·3091244	+0·0992181	15·17	−0·3125387	−0·0865543
14·60	−0·3101008	+0·0960550	15·18	−0·3116579	−0·0896172
14·61	−0·3110455	+0·0928846	15·19	−0·3107464	−0·0926692
14·62	−0·3119585	+0·0897071	15·20	−0·3098045	−0·0957100
14·63	−0·3128396	+0·0865228	15·21	−0·3088322	−0·0987393
14·64	−0·3136889	+0·0833321	15·22	−0·3078297	−0·1017567
14·65	−0·3145063	+0·0801353	15·23	−0·3067971	−0·1047620
14·66	−0·3152917	+0·0769327	15·24	−0·3057345	−0·1077550
14·67	−0·3160450	+0·0737246	15·25	−0·3046420	−0·1107352
14·68	−0·3167661	+0·0705114	15·26	−0·3035198	−0·1137025
14·69	−0·3174551	+0·0672934	15·27	−0·3023680	−0·1166565
14·70	−0·3181120	+0·0640708	15·28	−0·3011867	−0·1195969
14·71	−0·3187366	+0·0608441	15·29	−0·2999761	−0·1225235
14·72	−0·3193289	+0·0576135	15·30	−0·2987363	−0·1254361
14·73	−0·3198889	+0·0543793	15·31	−0·2974675	−0·1283342
14·74	−0·3204165	+0·0511419	15·32	−0·2961697	−0·1312177
14·75	−0·3209117	+0·0479017	15·33	−0·2948432	−0·1340863
14·76	−0·3213745	+0·0446589	15·34	−0·2934880	−0·1369396
14·77	−0·3218049	+0·0414138	15·35	−0·2921044	−0·1397774
14·78	−0·3222028	+0·0381668	15·36	−0·2906925	−0·1425994
14·79	−0·3225682	+0·0349182	15·37	−0·2892525	−0·1454055
14·80	−0·3229011	+0·0316683	15·38	−0·2877845	−0·1481952
14·81	−0·3232015	+0·0284175	15·39	−0·2862887	−0·1509684
14·82	−0·3234694	+0·0251660	15·40	−0·2847652	−0·1537247
14·83	−0·3237048	+0·0219142	15·41	−0·2832143	−0·1564639
14·84	−0·3239077	+0·0186624	15·42	−0·2816360	−0·1591858
14·85	−0·3240781	+0·0154110	15·43	−0·2800306	−0·1618901
14·86	−0·3242159	+0·0121602	15·44	−0·2783983	−0·1645765
14·87	−0·3243212	+0·0089104	15·45	−0·2767391	−0·1672448
14·88	−0·3243940	+0·0056619	15·46	−0·2750534	−0·1698948

Neumann Functions—continued.

x	$G_0(x)$	$G_1(x)$	x	$G_0(x)$	$G_1(x)$
15·47	−0·2733413	−0·1725261	15·74	−0·2178739	−0·2356711
15·48	−0·2716030	−0·1751385	15·75	−0·2155071	−0·2376877
15·49	−0·2698386	−0·1777318	15·76	−0·2131203	−0·2396794
15·50	−0·2680484	−0·1803057	15·77	−0·2107136	−0·2416460
15·51	−0·2662326	−0·1828600	15·78	−0·2082874	−0·2435872
15·52	−0·2643913	−0·1853945	15·79	−0·2058420	−0·2455029
15·53	−0·2625248	−0·1879088	15·80	−0·2033775	−0·2473930
15·54	−0·2606332	−0·1904029	15·81	−0·2008943	−0·2492573
15·55	−0·2587168	−0·1928764	15·82	−0·1983925	−0·2510955
15·56	−0·2567757	−0·1953291	15·83	−0·1958724	−0·2529076
15·57	−0·2548102	−0·1977608	15·84	−0·1933344	−0·2546934
15·58	−0·2528205	−0·2001712	15·85	−0·1907787	−0·2564527
15·59	−0·2508068	−0·2025602	15·86	−0·1882055	−0·2581853
15·60	−0·2487694	−0·2049274	15·87	−0·1856151	−0·2598912
15·61	−0·2467084	−0·2072727	15·88	−0·1830077	−0·2615701
15·62	−0·2446240	−0·2095959	15·89	−0·1803837	−0·2632219
15·63	−0·2425165	−0·2118967	15·90	−0·1777434	−0·2648464
15·64	−0·2403861	−0·2141750	15·91	−0·1750869	−0·2664436
15·65	−0·2382330	−0·2164305	15·92	−0·1724146	−0·2680132
15·66	−0·2360575	−0·2186630	15·93	−0·1697267	−0·2695552
15·67	−0·2338598	−0·2208723	15·94	−0·1670236	−0·2710693
15·68	−0·2316401	−0·2230582	15·95	−0·1643055	−0·2725555
15·69	−0·2293987	−0·2252205	15·96	−0·1615726	−0·2740136
15·70	−0·2271358	−0·2273590	15·97	−0·1588253	−0·2754436
15·71	−0·2248516	−0·2294735	15·98	−0·1560638	−0·2768452
15·72	−0·2225464	−0·2315638	15·99	−0·1532885	−0·2782184
15·73	−0·2202204	−0·2336297	16·00	−0·1504996	−0·2795630

Investigation of the Upper Atmosphere, in co-operation with a Committee of the Royal Meteorological Society.—Twelfth Report of the Committee, consisting of Dr. W. N. SHAW *(Chairman)*, Mr. E. GOLD *(Secretary)*, Messrs. D. ARCHIBALD, C. J. P. CAVE, *and* W. H. DINES, Dr. R. T. GLAZEBROOK, Sir JOSEPH LARMOR, Professor J. E. PETAVEL, Dr. A. SCHUSTER, *and* Dr. W. WATSON.

A MEETING of the Joint Committee was held in the rooms of the Royal Meteorological Society on April 8, 1913. It was decided to continue the ascents at Mungret College, Limerick, with funds provided by the Royal Meteorological Society, and to approve of the allocation of the grant of 50*l.* made by the Association at Dundee to the purchase of instruments and balloons for the meteorologist accompanying the ice ship 'Scotia,' Mr. G. I. Taylor, Schuster Reader in Meteorology.

Ascents have been made at Mungret College on July 6, 31, October 4, November 7, 1912, January 3, July 3, 1913, and also on four days during the International week (May 5-10), when observations were obtained which, in conjunction with others made at Pyrton Hill and Eskdalemuir (forming with Limerick a nearly equilateral triangle), give a remarkable series in illustration of the structure of a cyclonic

disturbance having its centre near Limerick on three of the four days A brief summary of the results obtained is given in the accompanying table.

The results of ascents at Barbadoes have been discussed in a paper by Mr. J. S. Dines, read before the Royal Meteorological Society.

Mr. Taylor, who returned at the end of August, reports that owing to continued unfavourable weather and other conditions no ascents of registering balloons could be undertaken with any prospect of regaining the balloon and instrument. He succeeded, however, in obtaining a valuable set of kite observations, especially on occasions of fog, and a report on these will appear in due course.

In view of the possibility of a further opportunity of investigation over the ocean next spring, the Committee ask for reappointment with a grant of 25*l.*

Summary of Registering Balloon Ascents at Limerick, July 1912 *to July* 1913.

Date	Time	Maximum Height	Place of Fall: Distance	Place of Fall: Direction	H_c.	T_c.	Gradient Velocity	Gradient Direction	Approximate Pressure at Sea Level	Character of Curvature of Isobars, (a=anticyclonic, c=cyclonic, s=straight)
1912	a.m.	km.	km.	°	km.	°A.	m/s.	°	mm.	
July 6	7.15	15	55	320	10.1	221	?	?	765	No gradient
" 31	7.15	14.8	107	56	9.0	227	12	155	751	c
October 4	7.0	15.7	88	160	*	*	13†	225†	777	a
November 7	7.15	14.1	131	82	11.9	208	15	220	768	s
1913										
January 3	7.15	9.8	27	85	9.0	225	11	225	752	s
May 5	7.0	11.3	60	130	9.4	217	?	?	756	Irregular
" 6	7.12	14.9	12	30	8.2	225	13	330	750	c
" 7	7.7	10.5	32	355	7.8	223	17	350	743	c
" 9	7.13	14.2	56	327	7.3	222	13	130	744	c
July 3	7.17	15.3	66	192	11.9	207	7	7	770	a

* The temperature gradient above 9 km. is so irregular that no definite value can be assigned to H_c.

† Gradient at 6 p.m. At 7 a.m. the station was in the central calm area of an anticyclone

Radiotelegraphic Investigations.—Report of the Committee, consisting of Sir OLIVER LODGE (*Chairman*), Dr. W. H. ECCLES (*Secretary*), Mr. SIDNEY G. BROWN, Dr. ERSKINE MURRAY, Professors J. A. FLEMING, G. W. O. HOWE, *and* H. M. MACDONALD, Captain H. RIALL SANKEY, *and* Professor SILVANUS THOMPSON.

AT a meeting held on June 13, 1913, the Committee came to the conclusion that the most urgent and most profitable work they could promote was the investigation of the following large-scale phenomena:—

1. The influence of sunrise and sunset, of daylight and darkness, and of meteorological conditions, on the propagation of electric waves over long distances;
2. The origin and the laws of 'strays'—*i.e.*, natural electric waves.

These are subjects which seem particularly suitable for the British Association, since they are such as cannot be efficiently pursued by uncoordinated individual effort.

In order to promote the necessary widespread observations, the Committee propose to draw up a simple scheme of instructions which will be circulated to amateurs throughout this country, and also, with the permission of the Companies concerned, to operators on ships. These instructions would include directions for simultaneous observations of, for example, the strength of the time-signals from such stations as the Eiffel Tower, and the average strength and frequency of strays. The observations would subsequently be classified and reduced by this Committee; and it is felt that this work would open up at once an almost unexplored, and exceedingly promising, branch of research—one which cannot be entered upon in any other way. It is, of course, essential that the work should be carried out over a very large area and by very numerous observers; and after full consideration of this fact the Committee resolved to apply for a grant of 200*l*. to enable the work to be started in a thorough manner.

Establishing a Solar Observatory in Australia.—Report of the Committee, consisting of Sir DAVID GILL *(Chairman)*, Dr. W. G. DUFFIELD *(Secretary)*, Rev. A. L. CORTIE, Dr. W. J. S. LOCKYER, Mr. F. McCLEAN, *and* Professors A. SCHUSTER *and* H. H. TURNER, *appointed to aid the work of Establishing a Solar Observatory in Australia.*

THE following Resolution was passed by the Council of the Royal Meteorological Society in October 1912:—

'The Council of the Royal Meteorological Society desires to associate itself with the movement to establish a Solar Observatory in Australia and expresses the decided opinion that such an observatory in the longitude of Australia or New Zealand is essential for the elucidation of the connection between solar changes and meteorological conditions upon the earth. It regards with great satisfaction the opportunity at present afforded to the Government of Australia of acquiring the equipment necessary to initiate this work.'

The opportunity referred to was the offer of the balance of the necessary equipment of a Solar Observatory which comprised a spectroheliograph, pyrheliometer, and Littrow spectrograph. The Fisher Ministry did not at the time see its way to the immediate acceptance of this offer on the ground that 'the establishment of scientific observatories is a matter for the future, and the organisation of such institutions should perhaps be left in the hands of those who may at some future time be appointed to take charge of them.'

Mr. Fisher's Ministry passed out of office during the year and has been succeeded by that of Mr. Cook. The new Ministry has been

approached with a view to their carrying the intentions of the previous Coalition Cabinet into effect.

It is understood that the Commonwealth Government contemplates the erection of a Solar Observatory upon a large scale, but it is unlikely that any further step will be taken before the British Association visits Australia next year, when, it is officially announced, a report embodying observations of the intended site which have been made for a period of more than a year will be presented and further advice sought. News has reached England of the offer by Mr. Cawthron, of Nelson, New Zealand, of 15,000*l.* to erect a Solar Observatory in the neighbourhood of that town. Miss Proctor, to whom belongs the immediate credit of obtaining the munificent offer, had previously lectured in Australia in support of the Solar Observatory to be established in that country.

Need still exists for a Solar Observatory in lower southern latitudes than that of Nelson, New Zealand, and Mr. C. G. Abbot writes urging that the Australian Observatory shall undertake the study of Solar Radiation, for which he regards the conditions as favourable.

In spite of the Government's attitude towards the recent offer of apparatus, the Commonwealth will shortly accept delivery of the Farnham telescope. This is the last of the three telescopes accepted in 1909 when the Commonwealth Government offered 100*l.* for its repair and alteration for Australian latitudes. A prominence spectroscope has been added to it out of the funds provided.

At the International Solar Union at Bonn in August 1913, it was proposed by Professor Campbell, Director of the Mount Hamilton Observatory, that the resolution passed at Meudon in 1907 be reaffirmed, and that the desirability of the erection of an Australian station be again urged upon the Commonwealth Government.

Experiments for improving the Construction of Practical Standards for Use in Electrical Measurements.—Report of the Committee, consisting of Lord RAYLEIGH (*Chairman*), Dr. R. T. GLAZEBROOK (*Secretary*), Professors J. PERRY *and* W. G. ADAMS, Dr. G. CAREY FOSTER, Sir OLIVER LODGE, Dr. A. MUIRHEAD, Sir W. H. PREECE, Professor A. SCHUSTER, Dr. J. A. FLEMING, Professor Sir J. J. THOMSON, Dr. W. N. SHAW, Dr. J. T. BOTTOMLEY, Rev. T. C. FITZPATRICK, Professor S. P. THOMPSON, Mr. J. RENNIE, Principal E. H. GRIFFITHS, Sir ARTHUR RUCKER, Professor H. L. CALLENDAR, Professor T. MATHER, *and* Mr. F. E. SMITH.

THE republication of the Reports of the Committee from 1862 to 1870 and from 1881 to 1912 is now complete. The volume consists of about 800 pages, with several plates, and is published by the Cambridge University Press on behalf of the Association.

The Committee are indebted to Mr. R. K. Gray for a generous donation towards the expenses of the republication, and are glad to report

that the Council have taken over the volume as a publication of the Association.

During the year the death of Mr. G. Matthey, F.R.S., has deprived the Committee of a valued colleague. His ready help was always given when questions dealing with the purity of the metals required for the work of the Committee were under discussion.

In 1861 the first work to be undertaken by the Committee was the realisation of the absolute unit of resistance. In 1882, 1883, 1888, 1894, and again in 1897, other measurements were made by members of the Committee, and in this their last Report they are pleased to be able to announce a further development. The new Lorenz apparatus at the National Physical Laboratory is now complete, and measurements of resistance can be made by means of it with an uncertainty of not more than a few parts in 100,000. During the present year a large number of such measurements have been made, and the results obtained are now being prepared for publication.

A satisfactory feature of the machine is that it can be used at all times for absolute measurements, and the plans adopted for the re-determination of the dimensions of the coils ensure an accuracy in the future as great as that obtained in the recent measurements. The nominal values of the resistances measured are 0·001, 0·002, and 0·01 ohm. As an instance of the care taken, it may be mentioned that the dimensions of the coils have been measured with a current flowing through them, and the radius of a disc 53 cm. in diameter has been determined within 0·01 mm. when running at 1,200 revolutions per minute. Electrical methods of setting the coils parallel and coaxial with the shaft proved to be more sensitive than the usual methods, and a Wheatstone bridge with a condenser in one arm proved to be the most sensitive indicator of constancy of speed. This instrument, together with the Ayrton-Jones current balance, enables the fundamental electrical units to be realised with an accuracy sufficient for all present purposes. It is hoped to re-wind the coils of the current balance and leave them uncovered with paraffin wax so that their dimensions may be determined at any time.

The Committee are pleased to report that the original rotating-coil apparatus, designed by Lord Kelvin in 1861, is in good condition, and steps are being taken for its inclusion in the Science Museum, South Kensington. Some rough measurements of resistance were made by the apparatus in the spring of this year, and the coils used by Lord Rayleigh in 1882 were also experimented with. An account of the apparatus is given in the Secretary's 'Kelvin' Lecture to the Institution of Electrical Engineers.

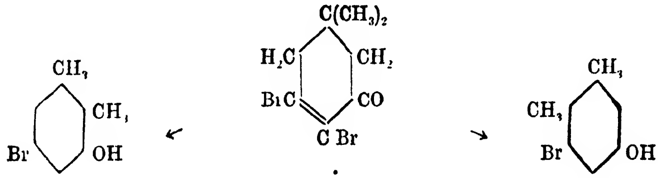
A statement on international comparisons of resistances and standard cells was included in last year's Report and sufficiently indicates the arrangements that have been made for the maintenance of constant electrical standards in the future. The Committee regard these arrangements as satisfactory. They do not ask for reappointment.

The Study of Hydro-aromatic Substances.—Report of the Committee, consisting of Professor W. H. PERKIN (*Chairman*), Professor A. W. CROSSLEY (*Secretary*), Dr. M. O. FORSTER, Dr. H. R. LE SUEUR, *and* Dr. A. McKENZIE.

1. *Bromoxylenols obtained from dimethyldihydroresorcin.*[1]—During the past year work has been largely concerned with the transformation of certain hydro-aromatic substances into bromoxylenols. These conversions were originally noticed[2] during the action of phosphorus pentabromide on dimethyldihydroresorcin, when the main initial products are not bromoxylenols, but are hydro-aromatic in nature, the principal ones isolated being dibromo- and tribromodimethylcyclohexenones.

As the original reaction is very complicated, it was decided to study the transformations using the pure above-mentioned cyclic ketones, and as a result of the work so far concluded it has been established that:

(*a*) The action of heat on dibromodimethylcyclohexenone (I) gives rise to 5-bromo-o-3-xylenol (II) and 6-bromo-o-4-xylenol (III).

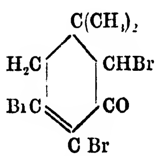


II. III.

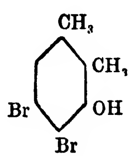
In the first of these rearrangements a methyl group has wandered, as previously noted, from carbon atom 1 to carbon atom 2; but in the second case from carbon atom 1 to carbon atom 6.

(*b*) The action of dilute alcoholic potassium hydroxide on dibromodimethylcyclohexenone gives rise to 5-bromo-o-3-xylenol and 4 : 5-dibromo-o-3-xylenol (V).

(*c*) Tribromodimethylcyclohexenone (IV) gives, under the influence of heat or alcoholic potassium hydroxide, mainly 4 : 5-dibromo-o-3-xylenol (V) and another bromoxylenol, which has not, so far, been characterised.



IV.



V.

The constitutions of 5-bromo-o-3-xylenol, 6-bromo-o-4-xylenol, and 4 : 5-dibromo-o-3-xylenol have been definitely established by synthetic methods.[3]

2. *Derivatives of isopropyldihydroresorcin.*—The method for the preparation of isopropyldihydroresorcin[4] has been improved so as to yield 75 per cent. of the theoretical amount of the dihydroresorcin.

[1] Proc. C.S., 1912, 28, 332. [2] J.C.S., 1903, 83, 110. [3] J.C.S., 1913, 103.
[4] J.C.S., 1902, 81, 675.

1-Isopropylcyclohexan-3-ol and 1-isopropylcyclohexan-3-one have been prepared, and it is intended to use them as starting-points for the preparation of several meta-terpene derivatives.

The Transformation of Aromatic Nitroamines and Allied Substances, and its Relation to Substitution in Benzene Derivatives.—Report of the Committee, consisting of Professor F. S. KIPPING *(Chairman)*, Professor K. J. P. ORTON *(Secretary)*, Dr. S. RUHEMANN, *and* Dr. J. T. HEWITT.

The Transformation of Acetylchloroaminobenzenes and the Chlorination of Anilides The Reactions of Chloroamines in Aqueous Solution.

[With W. H. GRAY, B.Sc.]

IN a previous report,[1] we have given a summary of the results of a large number of experiments on the transformations of chloroamines into the isomeric chloroanilides : Ar . NCl . Ac $\rightarrow$ Cl Ar . NH . Ac ; it was shown that this change could not be regarded as an intramolecular rearrangement, but consisted primarily of a reversible reaction of hydrogen chloride with the chloroamine : thus,

$$Ar.NCl.Ac + HCl \rightarrow Ar.NH.Ac + Cl_2 \rightarrow Cl\,Ar\ NH.Ac + HCl,$$

followed by a direct irreversible interaction of chlorine and the anilide.

In these experiments the medium was aqueous acetic acid containing not less than 50 per cent. of acetic acid. We have now examined the behaviour of acetylchloroaminobenzene in pure aqueous solution, and have discovered an interesting modification of the ordinary reaction.

The production of hydrogen chloride during the transformation of a chloroamine, in the presence of hydrogen chloride, was first indicated by Blanksma,[2] who found that the amount of this acid at the end of the reaction was slightly greater than that originally introduced. Moreover, it was demonstrated by Chattaway and Orton[3] that any change of the chloroamine which occurred in the presence of other acids—for example sulphuric—was invariably accompanied by the appearance of hydrogen chloride. The first quantitative experiments were made by Orton and Jones (compare Reports, 1910). These were carried out in an acetic acid medium containing from 0–35 per cent. of water, both in the presence and absence of various acids. The following table shows some of the results :—

TABLE I.

Medium	Acid	Time of Reaction	Chloroamine Disappeared	Chloroamine Reduced
Per cent.		Days	Per cent.	Per cent.
65 HA	none	22	50·8	6·04
”	H_2SO_4	13	49·16	11·2
”	HNO_3	7	54·96	3·72
”	$HClO_4$	9	48·0	18·67

[1] Reports, 1910. [2] *Recueil des Trav. Chim.* 1903, 22, 290. [3] *Proc. Chem. Soc.* 1902, 18, 200.

The following experiment serves as a comparison when a chloroamine, which cannot yield an isomeride, is used :—

65 per cent. HA	H_2SO_4	16 days	8·25 per cent.	8·1 per cent.

In the following experiments hydrogen chloride (1 molecular proportion) is initially present :—

		Per cent.
Glacial puriss.	Reaction complete	3·24
„ ordinary.	„	6·0
93·4 per cent. puriss.	„	1·96
75 per cent. puriss.	„	1·84

There can be little doubt as to the manner of this reduction. In all aqueous media some hydrolysis of the chloroamine occurs :—

$$Ar.NCl.NAc + H_2O \rightleftharpoons HClO + Ar.NH.Ac.$$

The reduction of hypochlorous acid is rapid in aqueous acetic acid even when carefully shielded from light. From an aqueous solution of chloroamine it is possible to distil off hypochlorous acid under reduced pressure. Thus at 25° and under 13·9 mm. the first 50 cc. of distillate from 250 cc. of a 0·1 per cent. solution of a chloroamine had a titre of 2·57 cc. of N/20 thio. No chlorine was found in the distillate, and there was no loss of chloroamine from the mother liquor other than by hydrolysis. The distillation of an equivalent solution of hypochlorous acid showed that the hydrolysis of the chloroamine is not extensive; for the first 50 cc. gave a titre of 30 cc. N/20 thio.

Reduction of the Chloroamine in Aqueous Solution.—The behaviour of acetylchloroaminobenzene in pure water would be expected to show a marked difference from that in concentrated acetic acid media on several grounds. If it be granted that the mechanism of the isomeric transformation consists in a reaction between chloroamine and hydrogen chloride, yielding anilide and chlorine, which then react to form the C-chloro-derivative, any extensive hydrolysis of the chlorine should lead to abnormalities and retard the production of chloroanilides. Jakowkin[4] showed that the reversible hydrolysis of chlorine, which is governed by the equation $K[Cl_2] = [HClO].[HCl]^2$, is very extensive in dilute aqueous solution. Thus, for example, over 90 per cent. of the chlorine at a concentration of 0·05 per cent. and less is present as hypochlorous and hydrochloric acids. From the form of the equation it will be seen that the proportion of free chlorine in the system would rapidly increase as the concentration of hydrogen chloride was raised; according to Jakowkin in solutions of hydrogen chloride above 0·1 *N* very little of the chlorine is present as hypochlorous acid. Above these limits of concentration of hydrogen chloride, therefore, the ordinary conversion of chloroamine would predominate.

Our experimental study is generally in harmony with these anticipations. With a high concentration of hydrogen chloride, the main reaction is a transformation of the chloroamine into monochloroacetanilides, but with low concentrations the reactions are greatly modified. In fact, the behaviour with hydrogen chloride then closely resembles that with other acids.

Aqueous solutions of acetylchloroaminobenzene change very slowly

[4] *Zeit. f. Physik. Chem.*, 1899.

if due regard is had to the purity of the water, and the protection of the solution from contamination with reducing materials. At 25° a 0·1 per cent. aqueous solution of this chloroamine drops only a few per cent. in titre in the course of several weeks; at 60°, however, 50 per cent. has disappeared in 38·5 hours. The addition of small quantities of an acid (1–2 molecular proportions, which give a concentration of 0·0058–0·0116) increases the rate of change, which is, however, still very slow; about 50 per cent. of the chloroamine disappears in one month at 25°, but in less than a day at 60°. There is no great difference between different acids, including hydrochloric, in their effect. Careful examination of the reactions, which lead to a fall in titre both in aqueous and highly dilute acids, discloses the fact that the principal change is a simple reduction of the chloroamine to anilide and hydrogen chloride; at the same time a small and very variable amount of chlorate appears. The production of chloroanilides is quite subsidiary. The most obvious interpretation of the facts is that the chloroamine is hydrolysed:

$$Ar.NCl.Ac + H_2O \rightleftarrows HClO + Ar.NH\ Ac$$

and the hypochlorous acid then reduced. It is not so easy to see how the latter change is brought about Both an aqueous solution of hypochlorous acid and also solutions containing a strong acid are quite stable. Moreover, the pure anilide does not reduce hypochlorous acid; the sole interaction is the equilibrium represented above. It seems most probable that the reduction is effected by aniline arising from the hydrolysis of the anilide—a change which has been shown to occur, but slowly, under the circumstances The hydrolysis of the anilide in pure water is yet slower than in acids, and hence the permanence of solutions of chloroamine in this medium at ordinary temperatures. The development of the characteristic colour reactions of aniline with hypochlorous acid in the course of the change is in harmony with this suggestion. Further, aniline is particularly effective as a reducing agent for hypochlorous acid, since one molecular proportion reduces several of the acid.

At higher concentrations of the acids (0·023 *N*) the specific effect of hydrogen chloride appears; but with the other acids the speed of hydrolysis and reduction is merely increased. But even with very great excess of hydrogen chloride, when the disappearance of the chloroamine is relatively rapid, the hydrolysis and reduction can still be detected as a subsidiary reaction. The formation of hydrogen chloride by reduction in the experiments with other acids is the obvious cause, as previously indicated, of the production of the small quantities of chloroanilide.

Method of Experiment.—Aqueous solutions of acetylchloroaminobenzene containing about 1 gram per litre were used, the reactions being carried out at 25° and 60°. After more than 50 per cent. of the chloroamine has disappeared, the hydrogen chloride is estimated. The remaining chloroamine (and the very small amount of hypochlorous acid) is reduced by arsenite, and the chloridion weighed as silver chloride. In order to estimate any chlorate which has been formed from the hypochlorous acid the reduction in another portion is carried out by sulphite. The chloroanilide is assumed to be given by difference, but it is quite possible that some chlorine disappeared in the oxidation of the aniline or in chlorinating free aniline. Some of the results are shown in Table II.

TABLE II.

Acid	Temperature	Percentage of Chloroamine converted into · (a) Cl′	(b) Cl′ + ClO$_3$′	(c) Chloroanilide
HCl (2 mols.) .	25°	54·24	8·12	37·64
H_2SO_4 (1 mol.)	,,	68·77	12·74	18·52
H_2SO_4 (4 mols.)	,,	65·39	15·46	19·14
HNO_3 (1 mol.)	,,	76·56	5·59	17·85
$(COOH)_2$ (1 mol.)	,,	74·36	—	25·64
HCl (10 mols.)	,,	12·2	—	87·78
HCl (20 mols.)	,,	7·73	—	92·28
HCl (4 mols.) .	60°	25·42	3·93	70·65
HCl (10 mols.)	60°	11·47	—	88·54
HCl (2 mols.) .	58·5°	43·76	9·36	46·98
Water . .	60°	63·59	—	36·42
H_2SO_4 (1 mol.)	60°	60·85	12·19	26·96
H_2SO_4 (10 mols.	60°	73·86	0·91	25·23

The times which the reaction occupies in various cases are very different. The chlorination of the anilide is in an aqueous medium an extremely rapid reaction (Orton and Jones, *loc. cit.*), and hence in circumstances when chlorine and anilide are present at relatively high concentrations, the chloroamine rapidly disappears, and a large proportion of chloroanilide is formed. This condition is realised when the concentration of the hydrogen chloride is sufficiently raised, for, as was shown in the foregoing, the hypochlorous acid is then replaced by chlorine: $H' + Cl' + HClO \rightarrow Cl_2 + H_2O$, and further hydrolysis of the chloroamine follows from disturbance of the equilibrium: $Ar.NCl.Ac + H_2O \rightarrow Ar.NH.Ac + HClO$.

The time of the half-change in a number of the experiments is shown in Table III.

TABLE III.

Experiment	Acid	Temperature	Half-period	Percentage of Chloroanilide
i	HCl (2 mols.)	25°	16·75 days	37·64
ii	HCl (2 mols.)	60°	8·2 hours	43·6
iii	HCl (4 mols.)	60°	2 8 hours	70·65
iv	HCl (10 mols.)	60°	40 5 mins.	88 54
v	H_2SO_4 (1 mol.)	25°	31·5 days	18·52
vi	H_2SO_4 (4 mols.)	25°	11·3 days	19·14
vii	H_2SO_4 (1 mol.)	60°	18·7 hours	26·96
viii	H_2SO_4 (10 mols.)	60°	4·9 hours	25·23

(i) A comparison of the experiments in which hydrogen chloride was used with that in which sulphuric acid was used at equivalent concentration (i with v and ii with vii), whether at 25° or 60°, shows that with double the production of chloroanilide, the speed of the disappearance of chloroamine is also approximately doubled.

(ii) With increase in the concentration of the hydrogen chloride, the production of chloroanilide rapidly increases. Raising the proportion of hydrogen chloride from 10 to 20 mols., roughly quadruples the speed, but only slightly raises the proportion of chloroanilide (from 88 to 92 per cent.).

(iii) Increase in the concentration of the sulphuric acid is accompanied by an increase in the rate of disappearance of the chloroamine. But in marked contrast to the effect of hydrogen chloride, the reaction is still

identical; the production of chloroanilide and the reduction remain in the same proportion.

These results illuminate some recent observations of Rivett[5] on the 'transformation' of acetylchloroaminobenzene in aqueous solution. In one series of experiments he used hydrogen chloride, but never below a concentration of 0·1351. Although the values for

$$k_I/[HCl]^2 \ (=0{\cdot}0413\text{–}0{\cdot}0419)$$

between the limits of 0·2702–0·4797 for [HCl], are very close, he seeks for an explanation of the slightly divergent values outside these limits of concentration only in the degree of ionisation of the hydrogen chloride, and in the secondary influences of the ions on one another or on the unionised molecules on the ions. Our demonstration of the existence of a subsidiary side reaction would indicate another cause for the divergence from strict constancy of the expression $k_I/[HCl]^2$. We have previously attempted (Reports 1910) to show how this relation, $k_I/[HCl]^2$ = const., is accounted for on our view of the transformation.

The speed of the formation of chloroanilides is given by the equation:

$$d\,[\text{chloroanilide}]/dt = k_{II}\,[Cl_2]\,[\text{anilide}] = k_{II}\,K\,[\text{chloroamine}]\,[HCl]^2,$$

since

$$K\,[\text{chloroamine}]\,[HCl]^2 = [Cl_2]\,[\text{anilide}],$$

from the equilibrium:

$$Ar.NCl.Ac + H' + Cl' \rightleftharpoons Cl_2 + Ar.NH.Ac\,;$$

Hence as chloroamine is the only variable,

$$d\,[\text{chloroanilide}]/dt = (k_{II}.K\,[HCl]^2)\,[\text{chloroamine}] = k_I\,[\text{chloroamine}].$$

Apart from the completeness of the ionisation of the hydrogen chloride, and apart from the slight increase in the concentration of the hydrogen chloride during the reaction, the quantity of chloroamine in the equation is supposed to be sensibly identical with that used in the preparation of the system, the reaction with hydrogen chloride being disregarded. These approximations would undeniably cause variation in the expression, $k_I/[HCl]^2$.

The final form of the equation is not changed if the hydrolysis of the chloroamine is taken, as seems necessary in an aqueous medium, as the first step.

$$Ar.NCl.Ac + H_2O \rightarrow Ar.NH.Ac + HClO \text{ and } HClO + H' + Cl' \rightleftharpoons Cl_2 + H_2O.$$

For

$$K_a\,[\text{chloroamine}]\,[H_2O] = [\text{anilide}]\,[HClO],$$
$$K_b\,[Cl_2]\,[H_2O] = [HClO]\,[HCl]^2,$$
$$K_a\,[\text{chloroamine}]\,/\,K_b\,[Cl_2] = [\text{anilide}]\,/\,[HCl]^2,$$

or

$$K\,[\text{chloroamine}]\,[HCl]^2 = [Cl_2]\,[\text{anilide}].$$

In Rivett's experiments with a pure aqueous medium, and also with other acids, he fails to recognise that the transformation of the chloroamine to the chloroanilides is merely a side-reaction, and that hydrolysis and reduction are the primary changes. His measurement of the rate of dis-

[5] *Zeit. f. Physik. Chem.*, 1913, 82, 201.

appearance of chloroamine in these solutions led him to the conclusion that hydrogen chloride was produced, but he does not determine the amount of hydrogen chloride, and thus misses this fact. Without attempting to examine his views as to the series of changes (reversible) by which he supposes hydrogen chloride to be produced, it may be stated that he does not suggest the reduction of chloroamine or hypochlorous acid. Moreover, it may be pointed out that the pink or purple colour referred to above, which appears during the decomposition of the chloroamine, is without doubt identical with the ordinary colour reaction of bleaching powder and aniline, and not as is suggested due to a compound, Ar . Nx . Ac, produced together with hydrogen chloride in a reversible reaction with the acid :—Ar . NCl . Ac + Hx $\rightleftharpoons$ Ar . Nx . Ac + HCl.

Summary.

1. The decomposition of acetylchloroaminobenzene in pure aqueous solution, or in the presence of all acids including hydrochloric, at a very low concentration is mainly hydrolysis and reduction of the hypochlorous acid:

$$\mathrm{Ar.NCl.Ac} + \mathrm{H_2O} \rightarrow \mathrm{Ar.NH.Ac} + \mathrm{HClO}$$
$$\mathrm{Ar.NH.Ac} + \mathrm{H_2O} \rightarrow \mathrm{Ar.NH_2} + \mathrm{CH_3.CO_2H}.$$
$$x(\mathrm{HClO}) + \mathrm{Ar.NH_2} \rightarrow (\mathrm{Ar.NH_2} + x\mathrm{O}) + x\mathrm{HCl}.$$

The transformation of the chloroamine into chloroanilides, which follows from the formation of hydrogen chloride, is quite subsidiary.

2. With higher concentrations of hydrogen chloride, more chlorine appears in the system from the reaction $\mathrm{H}' + \mathrm{Cl}' + \mathrm{HClO} \rightleftharpoons \mathrm{Cl_2} + \mathrm{H_2O}$. According to Jakowkin's measurements, chlorine is nearly completely hydrolysed in water at concentrations below 0·05 in the absence of excess of hydrogen chloride, whilst on the other hand in solutions of hydrogen chloride above 0·1 N, hydrolysis of the chlorine is nearly absent. Hence, now that chlorine and anilide are both at relatively high concentrations, the transformation of chloroamine to chloroanilide is the main reaction.

3. With acids other than hydrogen chloride, increase in the concentration cannot cause a similar change in the reaction.

4. The results of the study of the decomposition of chloroamine in aqueous solution are in complete harmony with the earlier view as to the part played by hydrogen chloride in the conversion of chloroamines to the isomeric chloroanilides.

The Committee asks to be reappointed with a grant of 20*l.*

The Report is a summary of the work which has been carried out. A detailed account of the experimental work will be published later in one of the chemical journals.

Dynamic Isomerism.—Report of the Committee, consisting of Professor H. E. ARMSTRONG *(Chairman)*, Dr. T. M. LOWRY *(Secretary)*, Professor SYDNEY YOUNG, Dr. C. H. DESCH, Dr. J. J. DOBBIE, *and* Dr. M. O. FORSTER. *(Drawn up by the Secretary.)*

A. *Rotatory Dispersion.*

THE past year has witnessed the culmination of an investigation that has a close relationship to the main line of research for which the

Committee is responsible. The marked progress that has been made in the study of rotatory dispersion may be shown by the list of papers which have been published during the year. These include a paper on

> 'Optical Rotatory Dispersion, Part I. The Natural and Magnetic Rotatory Dispersion in Quartz of Light in the Visible Region of the Spectrum' ('Phil. Trans.,' 1912, A. **212**, 261-97),

which will be followed shortly by Part II., in which the extension of the polarimetric method through the ultra-violet and infra-red regions of the spectrum will be described.

The application of these new physical methods to the study of chemical problems is described in a second series of papers, of which the following have been published already, or are in preparation for publication in the autumn:

'The Rotatory Dispersive Power of Organic Compounds.'

I. The Measurement of Rotatory Dispersion ('Trans. Chem. Soc.,' 1913, **103**, 1062-1067).

II. The Form of the Rotatory Dispersion Curves ('Trans. Chem. Soc.,' 1913, **103**, 1067-1075).

III. The Measurement of Magnetic Rotatory Dispersion ('Trans. Chem. Soc.,' 1913, **103**, 1322-1331).

IV. Magnetic Rotation and Dispersion in some simple Organic Liquids ('Proc. Chem. Soc.,' June 19, 1913).

V. A Comparison of the Optical and Magnetic Rotatory Dispersion in some simple Organic Liquids.

VI Anomalous Rotatory Dispersion ('Proc. Chem. Soc.,' June 5, 1913).

Attention may also be directed to a paper by Armstrong and Walker on 'The Causes of Variation in the Optical Rotatory Power of Organic Compounds and of Anomalous Rotatory Dispersive Power' ('Proc. Roy. Soc.,' 1913, A. **88**, 388-403), in which the close relationship between rotatory dispersion and dynamic isomerism is specially emphasised.

The general result of these investigations has been to show that a knowledge of the phenomena of dynamic isomerism is essential for the interpretation of optical rotation, especially in the case of liquids which show anomalous rotatory dispersion; conversely, it is believed that the study of rotatory dispersion will open up a new and fruitful field for the investigation of dynamic isomerism in the case of large groups of important compounds.

B. *Successive Isomeric Changes.*

The past year has also seen the completion of a long series of experiments on the complex isomeric changes which take place in the amide and piperidide of camphor-carboxylic acid. Nearly five years ago it was discovered that these substances were capable of giving inflected mutarotation curves. An investigation of 'The Equations for Two Consecutive Unimolecular Changes' (Lowry and John, 'Trans. Chem. Soc.,' 1910, **97**, 2634-2645) showed that inflected curves might be produced by two successive isomeric changes, but the experimental

curves were found to be more complex, giving indications of at least three successive changes involving four isomeric compounds. These experiments have been described in detail in two papers published during the past year (Glover and Lowry, 'Trans. Chem. Soc.,' 1912, **101,** 1902-1912; 1913, **103,** 913-924).

Experiments are now in progress with a view to investigating Forster's α-benzoyl camphor, the enolic form of which has been found to give inflected mutarotation curves when ethylene chloride is used as a solvent in place of chloroform. Even nitrocamphor has been found to give inflected curves if dissolved in ethylene chloride or in benzene (Lowry and Courtman, 'Trans. Chem. Soc.,' 1913, **103,** 1216), but it is believed that these are due to the gradual absorption of a catalyst from the walls of the polarimeter tube, and not to successive isomeric changes.

C. Influence of Light.

A series of experiments on the influence of light on isomeric change (Lowry and Courtman, 'Trans. Chem. Soc.,' 1913, **103,** 1214-1221) has shown that no marked acceleration is produced by exposing nitrocamphor, glucose, galactose or maltose to the action of powerful ultraviolet light. In the case of aminomethylene camphor, however, very marked acceleration occurs whilst the light is acting, but the action reverts to its original slow rate of change when the light is withdrawn. In the case of (enolic) α-benzoyl camphor a similar acceleration is produced, but the effect continues after the light has been extinguished; it is believed that this permanent stimulation of the action is due to the liberation of benzoic acid acting as a catalytic agent.

The Study of Plant Enzymes, particularly with relation to Oxidation.—Second Report of the Committee, consisting of Mr. A. D. Hall *(Chairman)*, Dr. E. F. Armstrong *(Secretary)*, Professor H. E. Armstrong, Professor F. Keeble, *and* Dr. E. J. Russell.

The inquiry has been continued in various directions during the past year, as shown by the following list of communications to the Royal Society:—

(*a*) Herbage Studies. II. *Lotus corniculatus* and *Trifolium repens*, cyanophoric plants. By H. E. Armstrong, E. F. Armstrong, and E. Horton.

(*b*) Studies on Enzyme Action. XIX. Urease. II. Observations on Accelerative and Inhibitive Agents. By H. E. Armstrong, M. S. Benjamin, and E. Horton.

(*c*) Studies on the Processes operative in Solution (XXX.) and on Enzyme Action (XX.). The nature of enzymes and of their action as hydrolytic agents. By E. F. Armstrong and H. E. Armstrong.

(*d*) Studies on Enzyme Action (XXI.). Lipase. III. By H. E. Armstrong and H. W. Gosney.

(*e*) The Rôle of Oxydases in the Formation of the Anthocyan Pig-

ment of Plants. By F. Keeble and E. F. Armstrong [in the 'Journal of Genetics'].

(*f*) The Formation of the Anthocyan Pigments of Plants. IV. The Chromogens. By F. Keeble, E. F. Armstrong, and W. N. Jones.

(*g*) The Formation of the Anthocyan Pigments of Plants. V. The Chromogens of White Flowers. By W. N. Jones.

(*h*) The Formation of the Anthocyan Pigments of Plants. VI. By F. Keeble, E. F. Armstrong, and W. N. Jones.

Considerable progress has been made in elucidating the part played by oxidising catalysts in the production of plant pigments. By means of suitable agents—in particular benzidine and α-naphthol—oxydases and peroxydases can be localised in plants both in the flower petals and in the vegetative parts. Evidence has been accumulated in favour of the hypothesis that the soluble sap pigments of plants are formed by the oxidation of a colourless chromogen through the agency of an oxydase. The method has been applied with success to certain problems in genetics.

The sap pigment may be reduced to the colourless chromogen by the agency of a reducing substance. Such a change takes place when the coloured cell is stimulated by a hormone (a substance which penetrates the cell membrane) under conditions in which the amount of water present is a minimum. When the conditions are reversed and there is an excess of water in the system, the chromogen is reoxidised. Both the reducing substance and the reduced pigment are soluble in aqueous alcohol of a suitable strength (90 per cent.). After extraction of a coloured petal by alcohol of this strength, both the solution and the extracted petal are colourless; but they can be caused to recover their original colour—the solution on evaporation of the alcohol and dissolution of the residue in water, the petal on warming in water. There is evidence that the flower contains an excess of chromogen beyond that normally converted into pigment. The reducing substance is not destroyed by boiling: it cannot therefore be classed as an enzyme. The experiments afford proof of the existence of an oxidising-reducing mechanism in the cell sap which controls the formation of flower colour and is itself regulated by the condition of concentration of the cell sap. Dilution favours oxidation, concentration alters the balance in the opposite direction.

Very little progress has yet been made in determining the chemical nature of the sap pigments. The researches of A. G. Perkin have made it almost certain that the soluble yellow pigments belong to the class of hydroxyflavones of which quercetin is the best known representative. On genetical grounds there is strong evidence in favour of regarding these yellow pigments as antecedents of the red, magenta, and blue sap pigments. By hydrolysis and subsequent reduction and oxidation or by hydrolysis and oxidation, red pigments have been obtained from a number of yellow flowers, such, for example, as the wallflower, daffodil, and primrose; it is possible that the coloured varieties of these species may arise in a similar manner.

The most fruitful discovery during the year has been the proof afforded by Chodat that the action of tyrosinase on an amino- acid,

e.g., glycine, gives rise to the production of formaldehyde, ammonia, and carbon dioxide. Elements are thus available for the production of all manner of complex compounds and the method has a wide application. Starting, for example, from a mixture of the glucoside arbutin with glycine, it is possible, by the action of emulsin and an oxydase at the ordinary temperature, to obtain first a red compound, then a brownish black substance, as well as a volatile compound possessing the characteristic odour of ripe plums. In short, both the colour and odour of the ripe fruit are obtained by a biological synthesis from the glucoside and an amino-acid. This synthesis appears of general application and is being further studied. Presumably the colours produced in this manner are those characteristic of the fruit and leaves of the plants rather than of the flower petals. The interaction appears to involve the oxidation of the phenolic constituent of the glucoside either to an *ortho-* or to a *para*-quinone, the condensation to quinhydrone and the interaction of this compound with ammonia and formaldehyde. *Meta-* phenols do not undergo the same transformation.

Erratic Blocks of the British Isles.—Report of the Committee, consisting of Mr. R. H. Tiddeman (*Chairman*), Dr. A. R. Dwerryhouse (*Secretary*), Dr. T. G. Bonney, Mr. F. W. Harmer, Rev. S. N. Harrison, Dr. J. Horne, Mr. W. Lower Carter, Professor W. J. Sollas, *and* Messrs. Wm. Hill, J. W. Stather, *and* J. H. Milton.

England.

Reported by the Rev. A. Irving, *D.Sc.*, *B.A.*, *and* Mr. Percy A. Irving, *B.A.*

Localities all in the Upper Stort Valley.

1. *Thorley, Herts.* (Boulder Clay.) 230 feet to 240 feet (O.D.).

(1) *Hypersthene Andesite* (8 in. by 7 in. by 4 in., weight 12 lbs.). From the Boulder Clay. This is the same rock as an erratic recorded as 'trap' in the 1911 Report, from Parsonage Lane, which has been recognised by Mr. G. Campbell Smith, of the British Museum (Natural History), as 'quite comparable with some of the Cheviot andesites, and may be referred to that district provisionally.' Subangular, columnar, both blocks extensively bleached by the leaching-out of the iron in weathering. Fragments of this rock not uncommon in the Rubble-Drift.

(2) *Coarse Phyllite* (13 in. by 12 in. by 5 in.) intersected by a network of vein-quartz, considerably weathered with oxide of iron on the divisional planes. It closely resembles the rock continuous with the coarser type of slate of the Swithland quarries (Charnwood).

(3) Angular slab (5½ in. by 5 in. by 1½ in). Fine-grained *sandstone* (coal-measures?), pressure-scarred and coarsely striated on one surface.

2. *Maple Avenue, Bishop's Stortford.* (Rubble-Drift.) 300 feet. (O.D.) All derived immediately from the glacial drift of the Herts plateau.

Phyllite (subangular), fragment of a larger slab (3 in. by 2 in. by ¾ in.): derived from the older and higher 'Drift' of the Herts plateau. This specimen strongly resembles some of the highly altered bedded 'ash' of Snowdonia.

Dolerite: *bomb* (broken), 2 in. in diam.

Flint: *extremely weathered and devitrified* (cortex of one extensively flaked), probably result of Miocene weathering of the quondam 'Mercian' chalk. (See Report in the 1911 volume, pp. 131 ff.)

Limestone: vermiculate, weathered, probably from the Cornbrash or the Lias (6 in. by 5 in. by 2 in.).

Sandstone, cuboidal block, very hard and fine-grained (2½ in. by 2 in. by 2 in.): Rothliegendes (?).

The erratics found here have mostly been obtained in the excavations connected with the horse skeleton described at Sheffield (in 1910), with further comparative anatomical notes at Portsmouth (1911), Section H; see also Report to the Special Committee in the 1911 Report (pp. 131 ff.). As a whole erratics from this source are far more extensively 'weathered' than those found in the Harlow Till, the Chalky Boulder Clay of the lower plateau, and the still younger Valley Boulder Clay at Thorley, where it is intercalated with the contorted gravels.

3. *Hockerill Vicarage.* (Excavations in Rubble-Drift.) 230 feet to 240 feet (O.D.).

(*a*) *Quartz-porphyry*: deeply weathered on exterior. Felspar more or less kaolinised throughout, suggesting a Bunter pebble (4 in. by 3 in. by 1½ in.).

(*b*) *Quartz-porphyry*: slab-like, subangular; more felsitic in texture than (*a*), slightly kaolinised.

Dolerite (3 in. by 2½ in. by 1½ in.): and several smaller fragments.

Hypersthene Andesite: several fragments.

Basalt: several fragments.

Rötelschiefer (3 in. by 3 in. by 1½ in.) from Rothliegendes.

Rhaxella Chert (4 in. by 2 in. by 3 in.): several smaller fragments.

4. *Hallingbury Road.* (Gravel-pit) (B.S. Urban Dist. Council.)

Quartz-porphyry (3 in. by 3 in. by 1½ in.).

Bedded Ash (6 in. by 5 in. by 3 in.).

Same with included fragments (3 in. by 2 in. by 1½ in.).

Palæozoic Conglomerate (5 in. by 4 in. by 3 in.).

Silicified Wood (?) (8 in. by 4 in. by 3 in.).

Boulder of vein-quartz (7 in. by 4 in. by 3 in.).

Several blocks of millstone-grit and of older grits (probably of Cambrian age).

All from the 'interglacial sands,' 210 feet to 230 feet (O.D.), which are strongly current-bedded: probably dropped by ice-rafts.

Reported by Mr. THOMAS SHEPPARD, *F.G.S.*, *F.S.A.*

Excavations continue to be made in the gravel pits at Burstwick and Kelsey Hill in Holderness. In the latter pit enormous quantities

of gravel have been removed, and have revealed many interesting mammalian remains, including the bone of a seal, which is the first record for that species from the Holderness drifts.

Ireland.

Reported by the Committee of the Geological Section of the Belfast Naturalists' Field Club.

The Committee record the extension of the area of distribution of Ailsa Craig Riebeckite-eurite to Moys, two miles west of the Roe, by Madame Christen; the rock has also been found for the first time at Limavady, Kilrea, Aghalee, Drumaneway, Dervock, and the White Mountain, north of Lisburn; at the latter locality it was found by Mr. Robert Bell, at an elevation of 800 feet.

Dungannon, Tyrone, Brickfield. Brown Boulder-Clay, overlain by black Boulder-Clay. Erratics:—Jasper, green rock series of Mid-Tyrone—red granite, ironstone nodules, dolomitic limestone, red limestone, concretionary iron ore, sandstone (probably local)—porphyritic syenitic granite, quartz-porphyry, probably Slieve Gallion—quartzite, diorite, epidiorite, Dalradian series, chalk, flint, gneiss, basalt, Carboniferous conglomerate.

Portstewart, Sand-hills. Epidiorites, metamorphic grits, granite, quartzites, arkose, porphyritic felsite, metamorphic sandstone, Dalradian, from Londonderry, Donegal, or Scotland—rhyolite (? trachyte), Tertiary series, Antrim—coarse granite, orthoclase rock (syenite group), granite-porphyry, syenite, Slieve Gallion, quartzite, porphyries—granite, riebeckite rock, Ailsa Craig—schist, altered diabase with epidote.

Limavady, Ballast-Pit near Railway Station. Erratics:—Riebeckite rock, Ailsa Craig—gabbro, hypersthenite (Slieve Gallion)—metamorphosed grit, epidiorites, quartzite, vein quartz—fine gneiss, granulite, Tyrone—red granites, hornblende schist—diorite, with granular ground.

Derrybeg Brickfield, Limavady, Boulder-Clay. Erratics:—Metamorphosed grit, Carboniferous sandstones, quartzite, diorite with granular ground, mica hornblende-schist, red and pink granites, crushed felsite, epidote granite with hornblende.

Moys, nearly four miles S. of Limavady, Gravel-Pit, Knockandunn. Erratics:—Riebeckite rock, Ailsa Craig—fine-grained granite—metamorphosed grits and sandstones, quartzite—pink granite, Carboniferous sandstone—gneiss.

Aghadowey, Gravel-Pit, Clare Hill. Erratics:—Micropegmatitic granite, quartz-porphyry, grey granites—crushed granite—quartzite, felsite, metamorphosed grit—vein quartz, epidiorite.

Kilrea Gravel-Pits. Erratics:—Riebeckite rock, Ailsa Craig—red and pink granites, green phyllite, rhyolite, diorite, gabbro—red Carboniferous limestone—coarse gneiss, dark red granite—quartzite.

Cavanmore Road, Gravel-Pit three miles from Kilrea. Erratics:—Hornblendic granite, quartzites, grey granite, red granites—meta-

morphosed sandstone, crushed felsite—limestone, probably Carboniferous—dark red granite, diorite, flints.

Garvagh Quarries. Boulder-Clay and 'Sands and Gravels.' Erratics:—Numerous red and pink granites, grey granite, hornblendic lamprophyre (camptonite?), andesite, pebbly grits, quartz-porphyries, syenite (Slieve Gallion)—mica schist, metamorphosed grits, quartzite.

Cookstown District, Gravel-Pits. Erratics:—Numerous red and pink granites, grey granite, aplite vein, felsites, felsite porphyries, syenites, diorites, crushed fragmental rock, ophitic gabbro, quartz-hornblende-porphyry, pink pegmatite, quartz-porphyry, Slieve Gallion—dolerite—banded granite, gneiss, metamorphosed sandstones and grits, quartzite (Dalradian).

Coalisland, Sand- and Gravel-Pits, fine current bedding. Erratics:—Syenite, grey, pink, and red granites, hornblendic granite, crushed felsite, felsite porphyries, quartz-porphyries, fine-grained gneiss, hypersthenite or pyroxenite, granite porphyries, lamprophyre, felsites, Slieve Gallion—gneiss—quartzite, reddened by hæmatite, red band of Slieve Gallion—andesite, Tyrone Devonian—flint.

Sherrygroom Gravel-Pit, about five miles South of Cookstown. Erratics:—Crushed conglomeratic sandstone (Dalradian), epidiorite (Dalradian), syenites, felsite porphyry, granite (aplite in), lamprophyre, pink granites, hornblende schist, Slieve Gallion—granites, Barnesmore (?)—andesite, Tyrone Devonian—diorite, Slieve Gallion or Tyrone axis—gneiss—flint, basalt, mica schist.

'Blue Door' or 'Finger' Gravel-Pit, near Cookstown. Erratics:—Red granites, syenites, hornblendic granites, Slieve Gallion—chalk, flint, quartzite.

Glasgow Hill, esker one mile north of Cookstown. Erratics:—Hornblendic granite, including pieces of diorite, coarse felsite porphyry, granite with inclusions of mica schist, hornblendic granites, syenite, diorites, porphyritic felsite, Slieve Gallion—granulitic gneiss, epidiorite, chalk flint breccia (local)—flints, basalts, chalk, quartz.

Aghalee, Section of Sands and Gravels overlying basalt in a quarry south of the Aghalee Bridge over Lagan Canal. Erratics:—Riebeckite rock, Ailsa Craig—granites, hornblendic granites, diorites, syenite, aplitic granite, quartz-felsite (altered rhyolite), Slieve Gallion—fine-grained sandstone, rhyolite, clay ironstone, jasper, flint, chalk, mica schist, white quartz.

Cullion Glen, North Slieve Gallion, Boulder-Clay overlying Carboniferous limestone. Erratics:—Carboniferous conglomerate—hæmatite and quartz, Red band Slieve Gallion—sheared felsite, Tyrone axis to West—andesites, quartz andesite, syenites, granites, hornblendic rock, diorites, camptonitic lamprophyre, local—chalk, flints, jasper, schist, red sandstone, quartz.

Carmean, esker close to Railway Station, about two miles North of Moneymore. Sands and Gravels. Sands of a red colour, and numerous pink granites common throughout the section—jasper, hæmatite ore, fine grained sandstone—granites, syenites, hornblende granite, diorite, Slieve Gallion—Carboniferous conglomerate, sandstone (probably Lower Carboniferous), crushed pegmatite.

Drumaneway, esker two miles west of Randalstown. Erratics:—Riebeckite rock, coarse and fine, Ailsa Craig—rhyolite.

Dervock, Carncullagh Gravel-Pit, one mile to East. Erratics:—Riebeckite rock, Ailsa Craig—rhyolite, pink granites, mica felsites, gneiss, mica schists, quartz schists, fine granite, quartzites, granite and quartz vein—granite, felsite with quartz and mica, sandstone.

Ballymoney, very small Gravel-Pits, *Seacon*. Erratics:—Rhyolite—felsite, quartz-felsite—felsite, altered rhyolite. *Heagles*:—Rhyolite—chalk with manganese dendrites, granite, granulitic felsite, felsite, ironstone, quartzite. *Ballybrates*:—Ferruginous sandstone, gneiss, felsite, red granite from N.E. Another small pit near (Darcus') consisted almost entirely of basalt boulders in a stiff matrix, but sandstone, red granite, and flint recorded.

Macfin, Gravel-Pit right bank of Bann near Macfin Station. Erratics:—Granites, diorites, aplites, quartzites, felsites, flint, quartz.

Coleraine, Hillman's Fancy Sand-Pit, near Railway Station. Erratics:—Riebeckite rock, Ailsa Craig—pink granites, porphyritic granite, crushed felsite, pegmatite vein in granite, diorite, granite in diorite, andesite, granite, quartz felsite, syenite, felsite, red granite, porphyritic felsite, jasperised rock (?), felsite, granite with micaceous knots, andesite—chalk, flint, quartz, quartzite.

Monaghan. Erratics:—Ferruginous jasperised shale, local, possibly Ballyjamesduff area—sandstone, local—white chert, Carboniferous limestone—from canal bank—calcareous pebbly sandstones, limestone, dolerite, calcareous grit, sandstones, all local—felsite (?), local. From Threemile House, S. of Monaghan—felspathic grit ?Silurian—felsite porphyry, (?) Slieve Gullion—quartzite, quartz vein—sandstone, local, metamorphosed grit, chert, local. From esker eight miles from Monaghan—calcareous sandstone with cemented coating of pebbles, felsp. grit, felsite, chert, limestone, sandstone, local—felsite porphyry, (?) Slieve Gullion.

Ballymurphy, *Belfast* (Springfield Brick-works), Boulder-Clay overlying Trias. Erratics:—Riebeckite rock, Ailsa Craig—chalk, flint, chalcedony, basalt, quartzite, quartz, clay ironstone, dolerite, Rhætic, Lias, Old Red Sandstone, weathered granite.

Portrush, New Waterworks, Boulder-Clay. Grey granite, West of Scotland.

Glenoe, Boulder-Clay. Rhyolite (Tardree type) and a few imperfect fossils.

Armagh. Granite invading hornblende rock, Tyrone axis.

Maghaberry, near Moira. Hornblendic granite—epidiorites, Donegal or Tyrone type, also Co. Derry type—quartzite, mica schist, Ailsa Craig rock 12 in. × 7 in. × 6 in.

White Mountain, North of Lisburn. Riebeckite rock, Ailsa Craig, from an elevation of 800 feet.

Lagan, Brickfield. Porphyritic felsite, hornblendic granite.

Investigation of the Igneous and Associated Rocks of the Glensaul and Lough Nafooey Areas, Cos. Mayo and Galway.—Report of the Committee, consisting of Professor W. W. Watts (*Chairman*), Professor S. H. Reynolds (*Secretary*), Mr. R. G. Carruthers, *and* Mr. C. I. Gardiner.

Mr. Gardiner and the Secretary visited the Lough Nafooey district in April 1913 and completed their work in the field. A general account of the structure is given in the report presented at the Dundee Meeting (1912), page 143, and the work of the present year did not disclose any additional facts of primary importance. It is hoped to bring an account of the Lough Nafooey district before the Geological Society during the coming session.

The Committee has now completed its work and does not seek reappointment.

The Preparation of a List of Characteristic Fossils.—Interim Report of the Committee, consisting of Professor P. F. Kendall (*Chairman*), Mr. W. Lower Carter (*Secretary*), Mr. H. L. Allen, Professor W. S. Boulton, Professor G. Cole, Dr. A. R. Dwerryhouse, Professors J. W. Gregory, Sir T. H. Holland, G. A. Lebour, *and* S. H. Reynolds, Dr. Marie C. Stopes, Mr. Cosmo Johns, Dr. J. E. Marr, Dr. A. Vaughan, Professor W. W. Watts, Mr. H. Woods, *and* Dr. A. Smith Woodward, *appointed for the consideration thereof.*

During the year, in response to the request of the Committee, lists of fossils characteristic of the various geological formations have been prepared and sent in by specialists, to whom the sincere thanks of the Committee are due. The arrangement of these lists into a whole has been undertaken and the result will be issued in print, at an early date, to the members of the Committee, and subsequently to teachers of geology throughout the United Kingdom.

The Committee ask for reappointment with a grant of 5*l*.

The Upper Old Red Sandstone of Dura Den.—Preliminary Report of the Committee, consisting of Dr. J. Horne (*Chairman*), Dr. T. J. Jehu (*Secretary*), Mr. H. Bolton, Mr. A. W. R. Don, Dr. J. S. Flett, Dr. B. N. Peach, Dr. R. H. Traquair, *and* Dr. A. Smith Woodward, *appointed for the further exploration thereof.*

The Committee now present a preliminary report regarding the excavations for fossil-fishes in the Upper Old Red Sandstone at Dura Den,

Fife. At the outset they desire to acknowledge the courtesy of Mr. Bayne-Meldrum, of Balmungo, the proprietor, who kindly granted permission to continue the work and gave facilities for extending the operations.

The excavations, begun so successfully by the Dundee local committee in 1912, ceased during the meeting of the British Association in September last. They were not resumed till May 5, 1913, when our Committee took the work in hand. They have been carried on continuously since that date with marked success.

A definite plan has been followed in conducting these excavations. The sandstone layer, rich in fish remains, is restricted to a zone about 2 inches thick. It lies at an average depth of 9 feet from the surface, and is overlain by about 4 feet of comparatively barren sandstone, capped by about 4 feet of loose superficial materials. It was arranged that the fish-bearing zone should be uncovered and removed in successive sections. The first section laid bare 11 square yards of the rich layer, the second 23 square yards, and the work now in progress will expose 28 square yards when completed.

The contractor was authorised to proceed with the third section on July 3, when the Chairman, the Secretary, and Mr. Don met at Dura Den. When this work is finished and the ground levelled, the outlay will exceed the British Association grant of 75*l.* Mr. Bolton, of the Bristol Museum, has kindly offered a contribution of 12*l.* on condition that some of the fossils be given to that museum. The Committee have accepted this offer, and should further funds be required, the money will be raised privately.

The fish-remains obtained from the first and second sections have been stored in an adjoining shed under lock and key. Those from the third section will be placed beside them. Dr. Smith Woodward is expected to undertake the determination of the fish-remains. A list will appear, together with a ground plan of operations, in the detailed report to be presented to Section C in 1914.

The Committee cordially acknowledge their obligations to Mr. Dunlop, from Dunfermline, who, at the request of the Chairman, undertook to superintend the work on the spot.

The Committee ask authority to distribute the fish-remains to various public institutions.

Geology of Ramsay Island, Pembrokeshire.—Interim Report of the Committee, consisting of Dr. A. STRAHAN (*Chairman*), Mr. HERBERT H. THOMAS (*Secretary*), Mr. E. E. L. DIXON, Dr. J. W. EVANS, Mr. J. F. N. GREEN, *and* Professor O. T. JONES.

THE Committee have to report that the grant made to them to aid Mr. J. Pringle in carrying out his researches in the West of Pembrokeshire has been spent.

They have also to report that considerable progress has been made

in the detailed mapping of the island, and a great number of fossils and rocks has been collected.

The southern half of the island, excluding the high ground of Carn Llundain, has been found to consist of Didymograptus bifidus shales, which have been invaded by a large mass of quartz-porphyry. At Foel Fawr these shales, with thick beds of tuff, are conformably overlain by dark grey rhyolites. Carn Llundain itself is built up of a series of rhyolites, brecciated and banded tuffs, and thin beds of highly altered sediments. A quartz-porphyry also occurs as an intrusive rock and is indistinguishable from the large mass mentioned above. At Ogof Colomenod there is a remarkable conglomerate. The lavas have proved to belong to a volcanic outburst which took place in Lower Llanvirn time.

In the northern half of the island a portion of the ground occupied by Lingula Flags and Didymograptus extensus beds has been mapped out, and a large collection of fossils has been made from the so-called Tremadoc deposits, the D. extensus beds, and the Lower Llanvirn.

Many of the rock specimens have been sliced, and together with the collection of fossils are undergoing investigation.

Neither the field-work nor laboratory examinations are yet complete, and the Committee ask that they may be reappointed with a grant of 10*l*.

The Old Red Sandstone Rocks of Kiltorcan, Ireland.—Report of the Committee, consisting of Professor GRENVILLE COLE *(Chairman)*, Professor T. JOHNSON *(Secretary)*, Dr. J. W. EVANS, Dr. R. KIDSTON, *and* Dr. A. SMITH WOODWARD, *appointed for the Exploration thereof.*

DURING the year further exploration of the Upper Devonian deposits at Kiltorcan, co. Kilkenny, has brought to light more material of the stem of *Archæopteris hibernica* and of, apparently, the stem of *Sphenopteris Hookeri*, of which up to the present scraps of foliage only had been found. Kiltorcan is particularly rich in remains of *A. hibernica* and of *Bothrodendron kiltorkense*. A few fish scales were also found.

The Committee thought it desirable to examine other possible sources of Devonian fossils. Accordingly Tallow Bridge (co. Waterford) was visited. The 'linear' plant recorded from the Old Red Sandstone there proved to be a *Bothrodendron*. It is very abundant at the particular exposure sketched by J. B. Jukes in 1855. A little material of (apparently) *Archæopteris hibernica* was found.

This locality would repay thorough exploration. Your Committee recommends its reappointment and a total grant for 1913-14 of 20*l*., inclusive of the balance of 9*l*. odd.

Occupation of a Table at the Zoological Station at Naples.—Report of the Committee, consisting of Professor S. J. HICKSON (*Chairman*), Mr. E. S. GOODRICH (*Secretary*), Sir E. RAY LANKESTER, Professor W. C. MCINTOSH, Dr. S. F. HARMER, Mr. G. P. BIDDER, Mr. W. B. HARDY, *and* Professor A. D. WALLER, *appointed to aid competent Investigators selected by the Committee to carry on definite pieces of work at the Zoological Station at Naples.*

SINCE the last report of the Committee was written the table at Naples has been occupied by the Hon. Miss Mary Palk from July 5, 1912, to April 16, 1913, and by Dr. Stuart Thomson from March 25, 1913, to April 16, 1913.

The Committee have received a grant of 50*l.* from the Council of the Association out of the Sir J. K. Caird benefaction, which can be used towards the contribution for the table next session.

The Committee ask to be reappointed with a further grant of 50*l.*

Dr. J. Stuart Thomson, of the University of Manchester, reports:—

'I beg to report that I occupied the British Association table at Naples for one month during the Easter vacation of 1913. I made histological studies on the muscles of the dorsal vibratile fin of *Hippocampus*, and the impregnation of these muscles with hæmoglobin and myo-hæmatin, and also worked at *Motella* with the same object in view. I devoted considerable attention to the general fauna, but more especially to the Alcyonaria of the Gulf of Naples. I collected and carefully preserved the brains of several genera of Elasmobranch fishes for future work by the Weigert Pal and Bielschowsky methods in connection with an investigation on which I am engaged on the *Telencephalon* of Selachians.'

Nomenclator Animalium Generum et Subgenerum.—Report of the Committee, consisting of Dr. CHALMERS MITCHELL (*Chairman*), Rev. T. R. R. STEBBING (*Secretary*), Dr. M. LAURIE, Dr. MARETT TIMS, *and* Dr. A. SMITH WOODWARD. (*Drawn up by the Chairman.*)

I HAVE to report that after consulting the Committee I paid over the grant in full to Professor Schulze last December.

He writes to me that the amount has been expended in helping to pay the large staff of specialists employed in carrying out the work, and he has furnished me with detailed accounts and statistics showing that he is making good progress with his gigantic task. The grant made by the Association is, of course, only a very small part of the cost of the work, but Dr. Schulze asks me to convey his thanks to the Association for the encouragement and assistance extended to him.

The Committee asks for reappointment, and hopes that the Association will be able to afford some further help for speeding the publication of the Nomenclator.

Zoology Organisation.—Report of the Committee, consisting of Sir E. RAY LANKESTER (*Chairman*), Professor S. J. HICKSON (*Secretary*), Professors G. C. BOURNE, J. COSSAR EWART, M. HARTOG *and* W. A. HERDMAN, Mr. M. D. HILL, Professors J. GRAHAM KERR *and* E. A. MINCHIN, Dr. P. CHALMERS MITCHELL, Professor E. B. POULTON, *and* Dr. A. E. SHIPLEY.

THE past session has been a quiet one as far as the work of the Committee is concerned. Some correspondence has been carried on regarding the question of the permanent endowment of the British table at Naples.

The Committee ask to be reappointed.

Belmullet Whaling Station.—Interim Report of the Committee, consisting of Dr. A. E. SHIPLEY (*Chairman*), Professor J. STANLEY GARDINER (*Secretary*), Professor W. A. HERDMAN, Rev. W. SPOTSWOOD GREEN, Mr. E. S. GOODRICH, Dr. H. W. MARETT TIMS, *and* Mr. R. M. BARRINGTON, *appointed to investigate the Biological Problems incidental to the Belmullet Whaling Station.*

THE Committee, having decided to further investigate the catch of whales during 1913, requested Professor W. A. Herdman to nominate one or more naturalists to proceed to Belmullet and also to direct and advise them as far as might be necessary. He selected two of his pupils, R. J. Daniel, B.Sc., and J. E. Hamilton, B.Sc., who proceeded to Belmullet on June 24. At the request of the Board of Agriculture and Fisheries Mr. Daniel was released on August 28 to take up a temporary appointment as Assistant Naturalist for Herring Investigations, but Mr. Hamilton still remains at the Fishery.

The following is an extract from a short report sent to the Secretary by Messrs. Daniel and Hamilton:

Blacksod, Belmullet, August 29, 1913.

Since June 26 we have examined altogether thirty-eight whales, of which twenty-eight have been Common Rorquals. The remainder consisted of six Sperm Whales, all males, three Sibbald's Rorquals, and one Humpback. A complete set of standardised measurements has been taken of each whale. The length and sex of the whales caught at the neighbouring whaling station on Rusheen Island have also been procured.

Four fœtus of the Common Rorqual have been examined; they were not sufficiently small to be of embryological interest. The smallest, which had been about four feet long, was almost completely destroyed by the explosion of the bomb, and was considerably decayed.

The stomachs have been examined to ascertain the food of the different species, but we believe that there is nothing of importance to record. The Schizopod, which is the principal food of the Balænopterid whales, has been noted in many Rorquals, and also in the single Humpback examined. A nearly complete cuttlefish of very large size was taken from the stomach of one of the Sperm Whales.

The external parasites found include *Penella* and *Balænophilus* on the Common Rorqual, *Cyamus* and *Conchoderma* on the Sperm Whales, and a large *Balanus*-like Cirripede on the *Megaptera*. Of internal parasites the sole

trematode was *Monostomum* from *Balænoptera muscularis*. In *B. sibbaldii* a cestode and an echinorhynch were found, in *Physeter* nematodes and echinorhynchs, and in *Megaptera* a large echinorhynch.

In the whalebone whales we discovered a peculiar dendritic tubular process projecting into the vena cava at the level of the kidneys. It appears to be the blind termination of a series of branching tubes ramifying in the kidney, and is nearly always stuffed with mineral matter in small irregular masses.

Although not as yet fully assured on the point, we are inclined to think that Burfield's 'Problematical Organ' will prove to be the external aperture of a mass of gland-like tissue situated between the mandibles at the symphysis.

Experiments in Inheritance.—Sixth Report of the Committee, consisting of Professor W. A. Herdman *(Chairman)*, Mr. R. Douglas Laurie *(Secretary)*, Professor R. C. Punnett, *and* Dr. H. W. Marett Tims.

The final report is unavoidably held over, and pending its presentation to the Association next year the Committee ask to be reappointed without a grant.

Marine Laboratory, Plymouth.—Report of the Committee, consisting of Professor A. Dendy *(Chairman and Secretary)*, Sir E. Ray Lankester, Professor Sydney H. Vines, *and* Mr. E. S. Goodrich, *appointed to nominate competent Naturalists to perform definite pieces of work at the Marine Laboratory, Plymouth.*

During the past year the use of the table has been granted to Professor J. Playfair McMurrich, of the University of Toronto, for one week, in order to enable him to procure specimens of the various Sagartiidæ that are to be found in the neighbourhood; also to Mr. W. O. Redman King, B.A., of the University of Leeds, for a fortnight, to enable him to investigate the temperature coefficient of the developing egg and the enzymes in the ova and spermatozoa of echinoderms.

Natural History, &c., of the Isle of Wight.—Report of the Committee, consisting of Mr. Clement Reid *(Chairman)*, Professor J. L. Myres *(Secretary)*, Mr. O. G. S. Crawford, Mr. W. Dale, Professor E. B. Poulton, *and* Dr. A. B. Rendle, *appointed to co-operate with local bodies in acquiring and arranging collections to illustrate the Natural History, Geography, and Antiquities of the Isle of Wight.*

In 1912 arrangements were made for transferring further archæological collections to Carisbrooke Castle, and half the grant was devoted to this purpose. There was, however, no room available in the Castle for anything but the archæological collections; and a recent visit by the Chairman of your Committee shows also that this old castle is scarcely suitable for the purpose.

The other available collections are almost entirely geological. For these, excellent accommodation has been found in the public library at Sandown. Here a well-lighted large room has been devoted to them, and they will be properly cared for. The cases from the old museum at Newport have now been removed to Sandown, and with a certain amount of adaptation and repair they will do very well. The whole of the specimens, however, require re-tableting and cleaning. The Committee has devoted the remainder of the grant to this work, which is now being carried out by a local committee.

Your Committee does not ask to be reappointed.

Atlas, Textual, and Wall Maps for School and University Use.—Report of the Committee, consisting of Professor J. L. MYRES *(Chairman)*, Rev. W. J. BARTON *(Secretary)*, Professor R. L. ARCHER, Dr. R. N. RUDMOSE BROWN, Mr. G. G. CHISHOLM, Colonel C. F. CLOSE, Mr. G. F. DANIELL, Professor H. N. DICKSON, Mr. O. J. R. HOWARTH, Colonel Sir D. A. JOHNSTON, *and* Mr. E. A. REEVES, *appointed to inquire into the Choice and Style thereof.*

THE Committee was appointed at the Dundee Meeting of the Association, and has spent its first year in preliminary work in two principal directions. One Sub-Committee has devoted itself to questions of content and arrangement; another to questions of style and draughtsmanship. The former necessarily had to settle many important points before the cartographical aspect of the matter could be discussed with profit; but the members of the Cartographical Committee have taken the opportunities of map-inspection which are described below to meet the members of the Contents Committee and discuss general points of principle.

The needs of junior and senior students differ widely, and it was found necessary from the outset to deal with them separately. But throughout the inquiry it has been the object of the Committee to provide as far as possible for a senior and a junior atlas which should be consistent in their general plan and execution. In order to keep in touch with the actual needs of teachers, and with the current practice of map-publishers, the Committee held one of its meetings at the School of Geography in Oxford, where it was able, by the courtesy of Professor Herbertson, to consult a very large collection of atlases, British and foreign, and to frame a series of questions for circulation among teachers and also among the Directors of Education in the larger administrative areas. The replies to these questions, so far as they shall have been received, are to be discussed at a conference to be held in connection with the Birmingham Meeting of the Association, and will be summarised in an Appendix to this Report. The questions, meanwhile, are printed below.

The Cartographical Sub-Committee will then be in a position to draft recommendations with fuller knowledge of the limiting conditions of

size, shape, and eventual cost, than would have been the case if it had begun its part of the work earlier.

The Committee therefore asks to be reappointed. It also asks for a grant to enable it to prepare the specimen sheets of maps which are already seen to be essential, if the Committee is to illustrate adequately the practical reforms which it hopes to recommend in map-production and to obtain the criticisms both of teachers and of publishers on the many points of detail and execution which arise at every stage.

The Committee desires to express its thanks to the many teachers and geographers whom it has consulted, and particularly to the Royal Geographical Society and the Oxford School of Geography for the opportunity of holding meetings and inspecting collections of geographical material.

Letter and Questions addressed to Teachers and Directors of Education.

Dear Sir.—The above Committee, appointed by Section E (Geography) at the Dundee Meeting (1912) of the British Association, hopes to present a preliminary report for discussion at Birmingham in September 1913. That the discussion may be effective, we venture to send you (Enclosure 1) a portion of this report in draft, and to invite your co-operation and, in particular, replies to the appended questions.

It would enhance the value of the replies if you would kindly state (*a*) what type of school you have in mind, and (*b*) what atlas is at present in use in the school.

1. What maps would you wish to see in duplicate, physical and political?
2. What would be the order of utility for your purposes of the large scale maps of the British Isles (1) A, B, C, D, E; (2) *a*, *b*, *c* (Enclosure 2)?
3. What chief inconveniences have you remarked in existing maps, and especially
   (*a*) What regions are inadequately represented?
   (*b*) What maps contain too many names? What maps too few?

Any communication addressed to the Rev. W. J. Barton, The College, Winchester, before the end of August would be welcomed.

Thanking you for your generous assistance, we have the honour to be

Yours faithfully,

John L. Myres, *Chairman of the Committee.*
Walter J. Barton, *Secretary of the Committee.*

Enclosure 1.

Senior School Atlas.

'Royal' paper (25″ × 20″) will give a map 10½″ × 8½″, single page. Double-page maps should be mounted on guards.

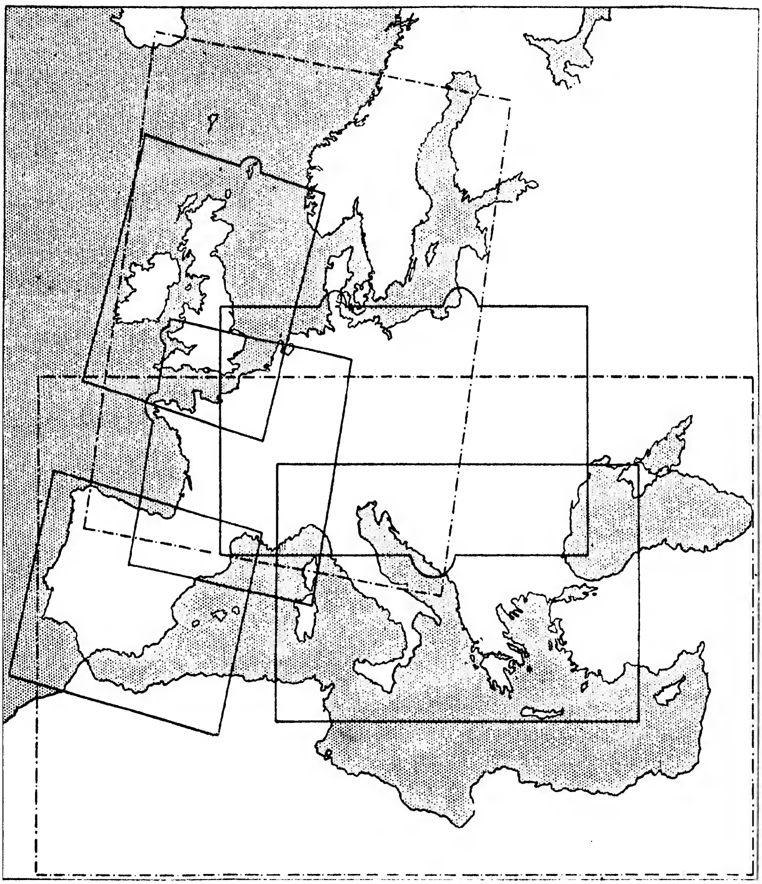
To make maps readily comparable, (*a*) all world maps should be on the same projection (Mercator's projection to be used for Map ' only); (*b*) few scales should be employed. The continents should be

shown on the same scale, and for larger scale maps simple submultiples of this scale should be used.

List of Maps.

World Maps.

1. Maps of a selected region, to exhibit scales, methods of showing relief, &c.
2. Hemispheres, heights, depths: section along 45° N.



European areas to be shown are enclosed by broken lines (Maps 13 and 17A) and continuous lines (Maps 14, 15, 17B, and 18).

3. Hemispheres, political: inset River Basins.
4. Hemispheres, population, density: Races inset.
5. Polar Regions: Land and Sea Hemispheres.
6. Vegetation: Ocean Currents.

7. Mercator (Australia repeated), showing Commercial Highways and Development.
8. Temperature: January, July, Year, Annual Range.
9. Pressure and Winds, two or four months. Rainfall: Year, Seasonal.

Europe.

10. Europe (20 million), physical. Inset (40 million), temperature: January, July.
11. Europe (20 million), political. Inset (40 million), rainfall, seasonal.
12. (*a*) Population, density; languages. (*b*) Minerals and manufacturing regions.
13. Mediterranean (10 million).
14. Central Europe (5 million).
15. Italy and Balkans (5 million).
16. Alps.
17. (*a*) N.-W. Europe (10 million). (*b*) Spain (5 million).
18. (*a*) France (5 million). (*b*) British Isles (5 million).
19. Large scale maps—*e.g.*, position of Vienna.

America.

20. (*a*) North America (40 million), physical. Inset (80 million), temperature.
(*b*) North America (40 million), political. Inset (80 million), rainfall.
21. (*a*) U.S.A. (20 million). (*b*) Atlantic Coast (10 million).
22. Canada (20 million), and Special Areas.
23. S. America (40 million), political. S. America (40 million), physical.

Asia.

24. Asia (40 million), physical. Inset (80 million), temperature: January, July.
25. Asia (40 million), political. Inset (80 million), rainfall.
26. Southern Asia (20 million).
27. China and Japan (20 million); Palestine.
28. India, political (large scale); climate.

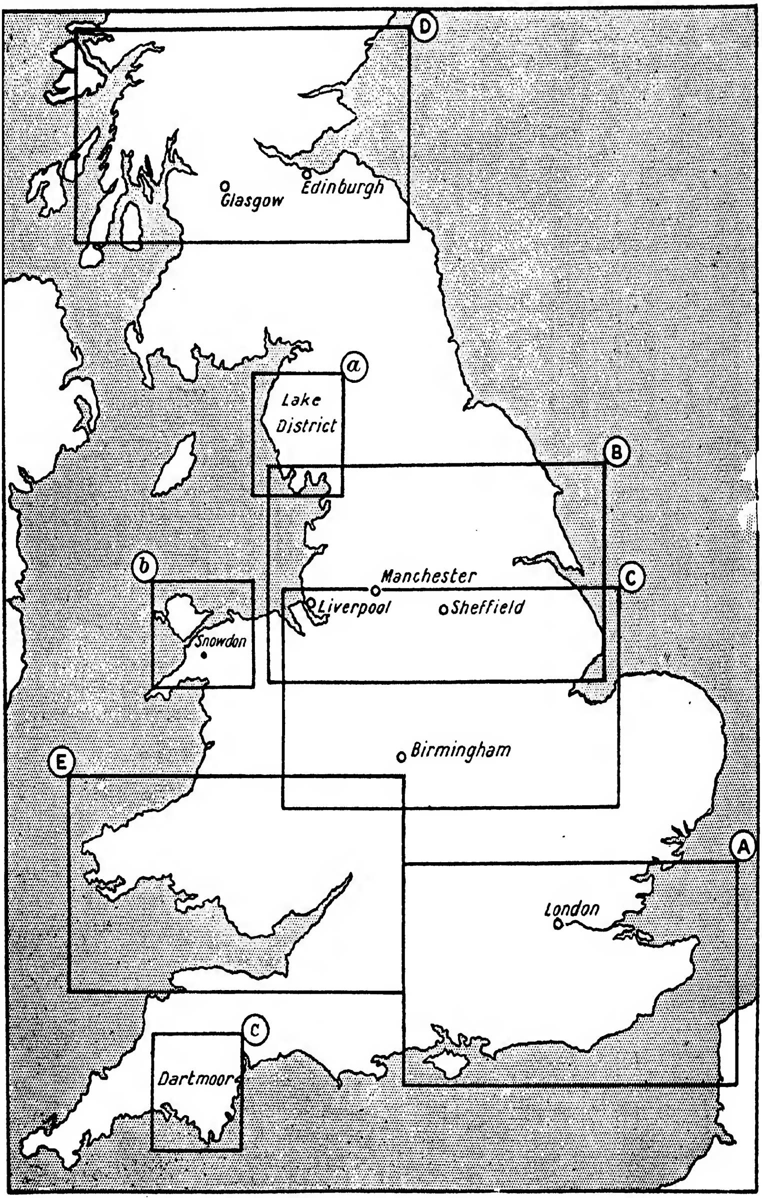
Australasia.

29. (*a*) Oceania, including East Indies (40 million), political. (*b*) Australia (20 million), physical.
30. (*a*) E. Australia, (*b*) New Zealand, larger scale.

Africa.

31. Africa, physical (40 million). Political (40 million).
32. S. Africa (20 or 12 million). Insets, W. Africa, Egypt, temperature, rainfall.

ENCLOSURE 2.



A, B, C, D, E are areas, some of which might be shown by double-page maps on a large scale (*e.g.* 1 : 500,000) ; *a*, *b*, *c*, single-page maps of holiday areas on a still larger scale (say 1 : 200,000).

British Isles.

England and Wales, Scotland and Ireland, physical and political (2 million).

Special regions, A, B, C, D, E, 1: 500,000.

Special regions, *a*, *b*, *c*, 1: 200,000.

Climate, Geology, Population, &c., to be determined.

About 40 double pages in all.

For a *Junior School Atlas*, one map of each continent (physical, with political boundaries shown in red) would meet all needs. Maps 4 and 5 would be combined; also 8 and 9 (temperature and rainfall only). For 26 and 27, India, China, and Japan (20 million) might be substituted, and the following maps omitted—viz. 12, 15, 16, 17, 19, 21B, 22, 29A, and 30A, together with 18A if France were shown on Map 14.

Geographical Teaching in Scotland.—Report of the Committee, consisting of Dr. J. HORNE *(Chairman)*, Mr. T. S. MUIR *(Secretary)*, Dr. R. N. RUDMOSE BROWN, Dr. W. S. BRUCE, Mr. H. M. CADELL, Mr. G. G. CHISHOLM, Mr. J. COSSAR, Professor H. N. DICKSON, Professor P. GEDDES, Professor A. J. HERBERTSON, Dr. J. SCOTT KELTIE, Mr. J. MALLOCH, Mr. J. MCFARLANE, *and* Dr. M. NEWBIGIN, *appointed to inquire into the present state thereof.*

THE following questions were issued in the form of a circular to all the Secondary and Higher Grade schools, and to some of the Elementary schools in Scotland, care being taken in the latter case to select representative areas:—

1. How many hours per week are devoted in your school to the teaching of Geography in (*a*) the Qualifying stage? (*b*) Intermediate stage? (*c*) Post-Intermediate stage?
2. Has that time increased, diminished, or remained stationary as compared with previous years? (*a*) Qualifying? (*b*) Intermediate? (*c*) Post-Intermediate?
3. What is the staple subject in your school outside of English? How many hours per week are devoted to it? (*a*) Qualifying? (*b*) Intermediate? (*c*) Post-Intermediate?
4. (*a*) How many candidates did you present in 1912 for the Leaving Certificate in Geography? (*b*) What proportion did the number of candidates bear to the total Leaving Certificate candidates from your school?
5. (*a*) Have you a 'qualified' teacher of Geography? (*b*) Is any 'practical' work done? (*c*) What kinds of maps and atlases are in use?
6. Please add any remarks you think may prove helpful to the Committee.

From the replies received, and from other sources, a considerable mass of information has been accumulated which has enabled the Committee to come to what it believes are trustworthy conclusions.

I. It is clear that in very many Elementary schools, especially in

country districts, Geography teaching is still on the old lines. To quote from one correspondent: 'All elementary teachers (in my district) are of the old school—*i.e.*, text-book, map, and memory. I find great difficulty, more in this than in any other subject, in getting them to teach Geography in a reasonable and attractive way.' The causes of this unfortunate state of matters are: (1) lack of knowledge on the part of the teachers, due to the extremely limited opportunities for acquiring instruction; (2) the reluctance, frequently the refusal, of School Boards to supply modern equipment, even such essentials as proper text-books and physical wall-maps. Some Boards issue admirable lists of approved text-books, &c., but, rightly or wrongly, many teachers are of opinion that the smaller their annual bill for such things is the more favourably they are looked upon by their employers. Teachers here and there exist who, at the expenditure of their own time and labour, construct wall-maps and simple instruments; but the ordinary elementary teacher who has to undertake many subjects has little, if any, leisure to devote to special work in one of these subjects. Nor can it reasonably be expected of him.

The 'Memorandum on the Teaching of Geography in Scottish Primary Schools' issued by the Scotch Education Department in 1912, in spite of some defects which need not be mentioned here, as they have already been noticed in several geographical reviews, undoubtedly marks a great advance, and will promote the setting up of a higher standard than before in Elementary schools.

It is advisable that classes for teachers be held in suitable centres all over Scotland. The experiment has been tried in at least one place with considerable success, and correspondents indicate that the demand for such instruction is both strong and widespread. Secondly, pressure should be brought to bear upon School Boards by inspectors or by other means to equip their schools with at least modern text-books and physical wall-maps.

II. In the Intermediate stage (ages 12 to 15) a higher standard of teaching is maintained. The Intermediate Certificate examination is here the end in view. Geography is compulsory, but is counted as part of English on the basis of 100 marks to English and 50 to Geography. No time allowance for teaching is prescribed, but one and a half hours per week is recommended. Needless to say, that allowance is rarely exceeded. Six schools only reported an allowance of more than two hours, one of them giving three hours.

The Committee notes with satisfaction the recent improvement in the type of paper set in the Intermediate examination, but thinks it capable of improvement. The following is an account of the paper set in 1913, which was of the same character as those for some years past. The paper was divided into three sections: A, B, and C. Two outline maps were provided—one of the World, the other of the British Isles. Section A consisted of three parts: (*a*) to insert in their proper places names such as Borneo, Lake Chad, Tibet; (*b*) to show by a dot and write beside it towns such as Bilbao, Canton, Colombo; (*c*) either to write names of races in their native places—*e.g.*, Kafir, Dyak, Ainu—or to draw in the Arctic and Antarctic Circles and the two tropics. Section B also consisted of three parts: (*a*) two towns famous for certain industries—*e.g.*, cutlery, brewing, &c.; (*b*) indicating regions

of heavy and light rainfall; (c) inserting certain names—*e.g.*, Stranraer, the Lizard, &c. In all, 42 separate facts were asked to be recorded for a maximum of 26 marks. Both sections were compulsory, and choice was given only in the case of part (c) of Section A. Section C consisted of eight questions of a wide range, from which the candidate was expected to select two. The marks for this section amounted to 24, making up for the paper a total of 50.

In the compulsory sections it would be of advantage that some further choice be afforded to the candidates, that greater opportunity be given for displaying knowledge of places associated with current events, and that a more reasonable proportion of the marks be allotted to that part of the paper which exercises the intelligence of the candidate.

The written examination is supposed to be supplemented by an oral examination conducted by an inspector, but this is usually perfunctory, and in some schools the inspector pays no attention whatever to Geography. Throughout the Intermediate course a compulsory minimum time-allowance of three and a quarter hours per week would be very beneficial, and inspectors of Geography might encourage attempts at a higher standard of teaching.

III. In the Post-Intermediate stage Geography is no longer a compulsory subject, except in the case of junior students, who, however, are at no time examined as to their knowledge of Geography. In the Leaving Certificate examination Geography is separated from English, which is the only compulsory subject, is put on a level with other optional subjects, and is allotted 100 marks. It may form one of a 'group,' but the curriculum must then be submitted to the Scotch Education Department for its specific approval. This is not required if a school commits itself to English, Mathematics, and French; or to English, Mathematics, and Latin. It is distinctly laid down that Geography is on the same level with, for example, languages, and that a candidate must spend upon it an adequate amount of time. The Committee finds that the average amount of time spent upon languages at this stage is seven hours per week. The following tabular statement will help to make matters clear:—

	1912.	1913.
No. of candidates for Group Leaving Certificate	2,202	2,290
Successful	1,711	1,739
No. of candidates with Geography as part of Group	195	146
Successful	155	92
No. of candidates who sat Geography examination	319	212
Successful	227	116

From these figures it will be seen that while in 1912 Geography candidates formed only about 9 per cent. of the total number of Leaving Certificate candidates, in 1913 even that small proportion was reduced to a little more than 6 per cent. The presentations for Geography as a separate paper also fell from 124 to 66; while the number of candidates with Geography as part of their group fell from 195 to 146.

The Committee has received some information regarding 1912. It is aware of 70 candidates who were accepted by the Department, and who had had an hour and a half, or less, teaching per week. It is also

aware of 35 of these candidates who passed. This last piece of information was not asked for in the circular sent out, but some correspondents gave it voluntarily. These figures speak for themselves.

From the returns received it is definitely proved that the making an optional subject of Geography has practically killed it in the Post-Intermediate stage. Only seventy-two schools sent in information on this point. The average time allowance was just over an hour and a half per week; in nine schools it was more than two hours. Some give an hour or so for the first year, then drop it entirely. Twelve have dropped it altogether. The Committee is aware of some others which have made no returns, and which have also dropped Geography. It is a fair inference that a complete census would reveal many more. In only eleven schools has the time allowance been recently increased, and in most cases this increase has been from a totally inadequate to but a slightly less inadequate amount. The Committee is of opinion that this is a very serious matter. It finds that in many Secondary schools, some of them the largest and most important in the country, situated in great educational centres, the pupils cease to study Geography at the age of fifteen. Further, that the average time devoted to Geography up to that age is only an hour and a half per week. Now the time up to the close of the Intermediate stage should be devoted to providing that foundation of fact which is the basis of scientific Geography, and it is only in the Post-Intermediate stage that a pupil is mentally fitted to build upon that foundation by studying Political and Economic Geography—in other words, how man adapts himself to his environment, and how that environment reacts upon man. It is not considered necessary to emphasise the value of Geography as an educational subject beyond expressing the opinion that after a knowledge of the English language there is nothing more essential to the mental equipment of the modern Briton than a thorough grounding in Geography. This is impossible of achievement under the present regulations. It seems only reasonable that Geography be made a compulsory subject throughout the Post-Intermediate stage, and that in this stage also a minimum time allowance of three hours and a quarter per week be fixed.

IV. *Training Colleges.*—It may be explained that students preparing for the Teaching Profession in Scotland may either receive their training at the Training Colleges, where the course extends for two years, or may continue their professional training with a University course, or may first complete their graduation and then devote one year to their professional training under the auspices of the Provincial Committees for the Training of Teachers established in the four centres —Aberdeen, Edinburgh, Glasgow, and St. Andrews.

The University students in training at Edinburgh or Glasgow may include Geography among the subjects required for graduation at the University, but this is not possible at the other centres, where so far there is no University teaching of the subject.

The position of the subject varies considerably at the different centres. At the Training Colleges of Edinburgh, Glasgow, and St. Andrews, lecturers in Geography have been appointed, and at these centres instruction in Geography forms an integral part of the curriculum for all Training College students.

At Aberdeen Training College the previous training of the students and their knowledge of the subject are regarded as satisfactory, so that there is now no special instruction in the subject, and attention is confined to the methods of teaching Geography. The classes consist of thirty to forty students, and thirty periods are devoted to the methods of teaching Mathematics, Nature Study, and Geography, so that if the time is equally divided Geography can receive only ten periods.

At Edinburgh at least thirty periods are given to the study of Geography, and the classes consist of forty to fifty students. At Glasgow the Geography course extends to thirty periods, and for lectures the classes average eighty students, while for practical work they are reduced to twenty-seven. At St. Andrews sixty periods are devoted to the study of Geography, and the classes number twenty-five students.

The University students in training at the Edinburgh centre receive no instruction in Geography unless they elect to include the subject in their graduation course at the University; a considerable number do so, but the larger number, who do not, are being sent out each year—many to teach in Secondary schools—without any equipment to teach the subject so far as the Training College is concerned.

At Glasgow the subject has been dropped from the curriculum of the University students in training, and attention is confined to methods in teaching Geography, in spite of the fact that in very many cases the previous study of the subject has been quite insufficient.

Finally, recent legislation by the Scotch Education Department, and local conditions at several of the Training Centres, now make it quite possible for students who may have ceased the study of Geography after obtaining the Intermediate Certificate to complete their professional training without much, if any, further instruction in the subject.

In the opinion of the Committee it should be rendered necessary for all University students in training to have obtained the Leaving Certificate in Geography unless adequate instruction in the subject is provided in their professional course, or unless they include the subject in their graduation course at the University.

V. *Universities.*—Geography was first recognised by the Scottish Universities in 1908, when a lecturer was appointed as head of a new department in that subject in the University of Edinburgh. The lecturer has an ordinary class extending over the whole session (three terms) and two advanced classes, each of which is confined to a single term. From the first the ordinary class has qualified for admission to the M.A. examination, Geography being now one of the optional subjects in that degree. One of the advanced classes is a non-graduation class. The other, which is devoted especially to Economic Geography, is the qualifying class for an optional paper for the degree of M.A. with honours in Economic Science. In five years during which the ordinary class has been held, the attendance has been 48, 40, 116, 132, 98. The attendance at the advanced class varies from 5 to 10.

The only other Scottish University which so far recognises Geography is Glasgow, where the lecturer was appointed on similar conditions to those in Edinburgh in 1909. There Geography may now be taken as a subject for either the M.A. or the B.Sc. degree. The ordinary class is the qualifying class for the M.A., and the advanced

class for the honours degree of B.Sc., and was held for the first time last winter. The attendance at the ordinary class for the four years during which the lectureship has been in existence has been about 30, 65, 73, 94.

It should be added that under a recent regulation, which comes into force next year, the position of Geography in the preliminary examination for admission to the Arts and Science Faculties of Edinburgh University has been seriously prejudiced. Down to 1913 Geography was one of the branches under the head of English, which is a compulsory subject in the preliminary examination, but from 1914 onwards the only recognition of Geography is in connection with the history of the British people, one of the subjects included in the English syllabus. 'Candidates will be expected to show acquaintance with the social as well as the political history of the British people and the relevant geography.'

In conclusion the Committee is of opinion that while the worst result of the present regulations for the Post-Intermediate stage is that pupils leave school with a very imperfect and one-sided educational equipment, a subsidiary result of nearly as much importance may soon appear. It is that the majority of the pupils who intend to become teachers will not care to take up the study of Geography again after the lapse of two or three years. Thus the supply of capable teachers will diminish, and once more, as in the past, even in the Intermediate stage, Geography will be entrusted to the 'general' teacher, and it will fall back into its old position of memory work, unintelligent and uncomprehended.

Gaseous Explosions.—Interim Report of the Committee, consisting of Sir W. H. Preece (*Chairman*), Dr. Dugald Clerk (*Vice-Chairman*), Professor W. E. Dalby (*Secretary*), Professors Bone, Burstall, Callendar, Coker, *and* Dixon, Drs. Glazebrook *and* Harker, Lieut.-Colonel Holden, Professors B. Hopkinson *and* Petavel, Captain Sankey, Professors Smithells *and* Watson, Mr. D. L. Chapman, *and* Mr. H. E. Wimperis, *appointed for the Investigation of Gaseous Explosions, with special reference to Temperature.*

Note on the Proceedings of the Committee for the year 1912-13.

At the Dundee Meeting certain changes were made in the constitution of the Committee. Sir William Preece continues to be Chairman, but Dr. Dugald Clerk and Professor Hopkinson resigned the joint secretaryship. Dr. Dugald Clerk, however, consented, to the great satisfaction of the Committee, to act as Vice-President, and Professor Dalby was appointed Secretary.

The Committee allocated the whole of the grant to the Secretary, with the object of providing him with a permanent research assistant to carry on the work. The moment is favourable for this action of the Committee. The new laboratories of the Imperial College of Science and Technology are approaching completion, and it is intended by the governing authority of the college that these laboratories shall be

devoted to research. Professor Dalby is working on a scheme with Dr. Dugald Clerk for equipping one bay with internal-combustion engines. It is recognised that the Imperial College would be materially assisted in carrying out their ideals if the work of the Committee were concentrated in the new laboratories.

Owing to a delay in the completion of the laboratories it is not possible to present a report this year. Work, however, has been carried on with the old plant by Professor Dalby with the aid of a research scholar, and some important results have been obtained which will be communicated in due course. The general work of the Committee has also gone steadily on during the year.

Three meetings have been held at the City and Guilds (Engineering) College, at which the following Notes were presented and discussed:—

Note 26. 'The flow of heat from a charge of air subject to cyclical variations of state in the cylinder of a gas engine,'

and

'The comparison of the temperature readings of a platinum thermometer with the temperature computed from the pressure volume diagram.' By Professor Dalby.

Note 27. 'The flow of heat between a charge of air enclosed in a gas-engine cylinder and the walls of the cylinder when the charge is subjected to a cyclical variation of temperature.' By Professor Dalby.

Note 28. 'Leakage of charge.' By Professor Dalby.

Note 29. 'Gas-engine temperatures.' By Professor Hopkinson.

Note 30. 'The effect of compression ratio on the efficiency of a gas engine.' By Professors G. Asakawa and J. E. Petavel.

Note 31. 'Determination of leakage by the method of alternate compression and expansion.' By Dugald Clerk.

Note 26.—In this Note, which was presented last year, Professor Dalby drew attention to a method of testing and correcting for leakage in a gas-engine cylinder. A detailed explanation of this method was given in the note, which was accompanied by eight photographic records relating to the experiments referred to; these were carried out at one constant speed. The observations were made by two research students of the Imperial College—Messrs. Mawson and Begg—working under the direction of Professor Dalby.

Note 27. This Note is a record of the results obtained by applying the method to the same engine run at different speeds in order to ascertain the effect of speed on the leakage. The paper was accompanied by eleven large blue prints giving the data and the deductions drawn from them.

Note 28. There was considerable discussion at the Committee regarding the amount of leakage found, and at the request of the Committee Professor Dalby made some further experiments, the results of which are embodied in Note 28. This Note was accompanied by a blue print of two curves and a photographic record.

Note 29. Professor Hopkinson's Note consisted of general remarks relating to the importance of knowing the suction temperature and its influence on the heat flow.

Note 30. This Note relates to the efficiency of a gas engine with varying degrees of compression, and is embodied in a paper which is to be presented at the Birmingham Meeting of the Association.

Note 31. This Note, presented by Dr. Clerk, relates to experiments on the determination of the specific heat of gases, with special relation to the correction applied to eliminate the effect of the small amount of leak of charge.

Certain of the More Complex Stress Distributions in Engineering Materials.—Report of the Committee, consisting of Professor J. PERRY (*Chairman*), Professors E. G. COKER *and* J. E. PETAVEL (*Secretaries*), Professor A. BARR, Dr. C. CHREE, Mr. GILBERT COOK, Professor W. E. DALBY, Sir J. A. EWING, Professor L. N. G. FILON, Messrs. A. R. FULTON *and* J. J. GUEST, Professors J. B. HENDERSON *and* A. E. H. LOVE, Mr. W. MASON, Sir ANDREW NOBLE, Professor KARL PEARSON, Messrs. F. ROGERS *and* W. A. SCOBLE, Dr. T. E. STANTON, *and* Mr. J. S. WILSON, *appointed to report thereon.*

Report on Combined Stress. By W. A. SCOBLE, *B.Sc.*

INDEX.

(The small figures in the text refer to the bibliography.)

Historical.—Coulomb[1] appears to have been the first to study the kind of strain we now call shear, and he considered that rupture takes place when the shear of the material is greater than a certain limit. This is the first recorded Theory of Strength, but since it refers to rupture, the shear defined is a permanent set. Vicat[2] drew attention to the flow of metals when he discovered that the yield of iron is dependent on the time it is stressed, but Tresca,[9] by his extended researches, kindled great interest in this subject, and he also stated that the maximum difference of the greatest and least principal stresses is the measure of the tendency to rupture. Theories of molecular action were devised by various investigators to account for the viscosity and the elastic afterworking.* Love

* See *The Mathematical Theory of Elasticity*, Love, 2nd edit., p. 116.

points out that the stress difference theory of Tresca leads to a limit which is little different from the shear strain hypothesis enunciated by Coulomb. The Stress Difference Theory was applied by G. H. Darwin [13] and C. Chree.[14] It is probable that they were influenced by Tresca, and also by the knowledge that a brittle material fractures by shearing when loaded in compression.

The Maximum Strain Theory is usually named after St. Venant,[6] but he attributed it to Mariotte,[3] who wrote : 'que c'est le degré d'extension qui fait rompre les corps.' St. Venant adapted this theory to the elastic breakdown of a material by assuming that after the limit of mathematical elasticity is reached, the body will ultimately be ruptured if it has to sustain the same load.* He also rejected Coulomb's theory when applied to rupture in compression, and followed Poncelet,[5] who ascribed rupture by compression to the transverse stretch which accompanies a longitudinal squeeze.

Lamé [4] assumed that the greatest tension had a limiting value to ensure safety. This view was adopted by Rankine, who was followed by British and American engineers, but when known as the Maximum Stress Theory it is usually assumed to apply in compression as well as in tension.

A modification of the Stress Difference Theory was suggested by Navier, and is based on the assumption that the shear stress at failure is modified by the internal friction of the material to an extent proportional to the stress normal to the plane of the shear. Perry† has been the principal exponent of this modified shear stress theory in this country. He notices that cast iron, stone, brick, and cement fracture at angles greater than 45 degrees with the cross section. For cast iron the angle is $54\frac{3}{4}$ degrees, which corresponds to a coefficient of internal friction equal to 0·35. Perry also suggested that there is no internal friction in wrought iron and mild steel, in which case the modification is eliminated, and the simple law holds. Mohr [24] has proposed a further development of the shear theory to take account of the kind of stress which is developed within the body.

Poisson's Theory indicated that the ratio which bears his name should be $\frac{1}{4}$. The early determinations by Wertheim [7] have been noted here because they disproved the theory by giving different values, and thus had a great influence on the rariconstancy and multiconstancy controversy in the Theory of Elasticity.

1. *Theories.*

We desire to define the conditions which determine the failure of a material when subjected to any system of stress. Theories have been advanced which suggest as a criterion of strength: (*a*) the maximum stress; (*b*) the maximum strain; (*c*) the greatest stress difference, or shear stress or strain; (*d*) the maximum value of the shear stress modified by a friction term proportional to the stress perpendicular to the plane of the shear.

The shearing stress and the stress normal to the plane of the shear have received increasing attention, not always on the lines indicated by theories (*c*) and (*d*), but these have to a great extent eclipsed the other suggestions.

In a recent paper, Mallock [77, 78] considers the limit of shear and the limit of volume extension as the fundamental limits of a material, and failure is assumed to occur according to which is first reached.

* Todhunter and Pearson, *History of the Theory of Elasticity*, vol. ii., pt. i., p. 107.

† Perry, *Applied Mechanics*, 1898, pp. 345 to 348, 356.

Too frequently the complexity of our subject has not been realised, and confusion has followed the omission of conditions and limitations. This is particularly noticeable in early statements of theories, and has not been eliminated in some of the most important modern contributions.

2. *Failure.*

The laws of failure for materials are important to elasticians, experimentalists, theorists, and engineers, and we must inquire whether one definition of failure can be generally acceptable. The theory of elasticity is based on Hooke's Law which holds to the elastic limit, consequently the elastic limit is the fail point for the elastician, and also for the experimenter who calculates his stresses from formulæ based on Hooke's Law. But the elastic limit is not a well-defined point even under the most favourable conditions,* and many materials extensively used in engineering practice have no elastic range. In the case of steel the yield point has been taken for experimental purposes instead of the elastic limit,[23] and modern tests under simple loading indicate that these points coincide for some steels initially in a state of ease. Engineers are justified in considering fracture [79] because in many structures the yield point is exceeded locally (as in riveted joints), and where the stress intensity varies through the mass of the material the distribution at rupture is entirely different from that within the elastic range of the material.

These considerations lead to the suggestion that for the purpose of the present investigation experiments should be arranged with uniform distribution of stress, and then important data will be obtained at elastic failure and at fracture. Experiments which employ non-uniform stress distributions will give useful results at the elastic limit and possibly at the yield point of the material, but the data obtained at fracture or other complete failure in such cases is of no value for the present purpose.

3. *Materials.*

We have to consider materials with widely different mechanical properties,† and it is certain that all materials do not behave similarly when tested under identical conditions. To the present the distinction appears to have been between ductile and brittle materials,[23, 41] which is better than the frequent neglect of this consideration; but this is not a complete definition, and, furthermore, it does not readily enable the physical properties of a material to be defined with exactness. It is possible that Mallock's suggestions will lead to more accurate scales, and consequently to a knowledge of the relation between the elastic constants and the behaviour under any system of combined stresses.

4. *The Systems of Stress.*

The stresses may be referred to the three principal stresses. Each principal stress may be either a tension or a compression. In cases of simple tension or compression two of the principal stresses are zero. With two-dimensional stress one principal stress is absent, and we can have combinations of two tensions, two compressions, or one tension and one compression. There are corresponding combinations for three-dimensional

* The correspondence on this point should be consulted.

† Mallock [77] suggests relations between the unclassified mechanical properties, brittle, ductile, tough, &c., and the measurable constants of the substances to which they are applicable.

stresses, but in this case there is very little experimental evidence available. It is certain that some materials do not fail in the same manner under all systems of stress, and Mallock's double limit is an attempt to meet this difficulty,[77] by which the material is supposed to fail according to the limit which is first reached.

It is probable that each of the principal theories contains a germ of truth if its application be properly limited. Difficulty has arisen because a theory has been assumed to apply under too wide a range of conditions.

The experimental evidence will be shown later to indicate that a ductile body fails when the maximum stress difference (or shear stress) reaches a certain value. So far as is known, the intermediate principal stress is without effect on the failure. If the failure be limited to yield, this limit will apply for compressive as well as tensile stresses.

A brittle material appears to fracture at a definite maximum principal stress when this is a tension. Under compressive stress failure seems to be by shearing modified by friction on the plane of the shear.

Theories (*a*) and (*d*) are so far justified under definite conditions by the experimental evidence, and (*c*) is a particular case of (*d*), and not very different from it, which applies to ductile steels because the coefficient of internal friction is zero.[80]

It will be noticed that Mallock's double limits cover all the above if the shear theory is modified by friction, and maximum stress is used to replace the volume extension. The double limits apply to brittle materials, and the relation between them should be determined. It is difficult to conceive a volume extension limit, because in two-dimensional stress a material under tension in one direction would be strengthened by a compression perpendicular to the tension. Further, the very different strengths of most brittle substances in simple tension and simple compression are accompanied by very different strains at fracture, and a maximum strain theory could not always apply.

It is clear that tests will be incomplete unless they employ most of the possible combinations of the principal stresses.

5. *The Rate of Loading, and Repeated Loading.*

The most common and simplest method of applying the stresses is by a slow rate of increase so that the material fails under sensibly static conditions. In engineering practice combined stresses are also applied under rhythmically repeated and shock conditions. The former is of special interest because it is one of the most common cases of combined stresses, and causes fractures which resemble those of brittle materials under similar, but static loading. It is probable that the practical cases which involve shock will require special treatment, but some attention might be given to the matter in our investigations.

6. *The Mechanism of Failure.*

Consideration of this subject has been largely dissociated from that of combined stresses, to the detriment of both. That there is the closest connection is evident, and it is possible that a study of the mechanism of failure might be of assistance in the case of a material to which the more usual methods cannot be applied. The matter is noted here as a reminder rather than for present discussion.

Previous Researches.

7. *Early Engineering Tests.*

Reference has been made to the important experiments of Tresca,[9] which led him to support the stress difference theory of rupture for ductile materials, and his conclusions have been generally accepted. Most modern researches have differed from Tresca's because attention has been concentrated on the yield point or the elastic limit of the material.

Experiments on steel by the Committee of Civil Engineers are of interest because the tension and compression specimens were 1·5 inch diameter and 10 feet long, so that the longitudinal strains could be measured accurately. There was little difference in the stress at the yield point in any case, a result which supports the contention that the coefficient of internal friction for steel is zero, and that Theory (*c*) is a particular case of (*d*) to suit ductile steels.

Hodgkinson[8] found that cast iron fractured at stresses of 7 tons per square inch in tension, and 24 tons per square inch in compression. The form of the fracture in compression in common with those of other brittle materials has led to the acceptance of Theory (*d*) under these conditions, in the absence of direct experimental evidence. It is remarkable that the great differences in strength and form of fracture did not lead to an earlier recognition of the possibility of two limits for failure, at least for brittle substances.

The tests of iron and steel in different ways by Appleby[15] and Kirkaldy[16] were of great engineering importance, but since results are given for fracture they lead to no definite conclusions for our purpose. This applies also to the later work of Platt and Hayward,[17] which included tests of cast iron in tension, torsion, and shear, because Scoble[41] has concluded that cast iron yields too much before fracture to allow the elastic formula to be used to calculate the true breaking stress in torsion. The results of the shearing tests are not acceptable.

8. *Experiments with Ductile Materials under Combined Stresses.*

Wehage[18] tested circular steel and wrought-iron plates supported round their edges and loaded at their centres. The extension at the elastic limit was about half that in simple tension.

Carus Wilson's paper[20] on 'The Rupture of Steel by Longitudinal Stresses' describes an attempt to test the stress difference theory (*c*) employed by Darwin.[13] Tension specimens of rectangular cross section were tested to fracture when plain, with a 'V' notch, and with a 'U' notch on each side. He used the true mean stresses calculated on the contracted areas at fracture. The 'V' notched specimens were weaker and the 'U's' stronger than the original bar. The notches caused an uneven stress distribution across the breadth of a bar, which tended to weaken it; they also reduced the tension area more than that which resisted the shear. He concluded that the material fractured by shearing. He also found that the shear stresses in tension, and in double shear tests agreed very well if the true stresses at tensile fracture were taken.

Foppl[21] tested materials under a uniform pressure of 50,000 lb. per square inch and also with compression in two directions, and a third principal stress absent. His experiments led to no definite conclusions except that the uniform pressures applied did not cause rupture.

Guest[23] conducted by far the most important early research. He distinguished between brittle and ductile materials. Thin tubes of steel, copper, and brass were tested to yield under combinations of tension, torsion, and internal fluid pressure. The principal stresses were two tensions, or one tension and one compression, with the third always very small. An abstract cannot do justice to Mr. Guest's paper, which raised the experimental side of our subject to a higher level, and has directly suggested much of the more recent research. He concluded that the condition for initial yielding of a uniform ductile material is the existence of a specific shearing stress, and that the intermediate principal stress is without effect.

Coker[29] studied iron and steel under torsional stress, and included some data in relation to torsion with tension or bending. This paper indicates the general character of the effect of tension and bending on a specimen subjected to torque.

Wehage[35] presented no new experimental results. He contended that although two tensile stresses at right angles counteract one another when the extensions are considered, their destructive effect on the material is really superposed. The previous experiments of Guest prove him to be wrong. Mohr's Theory is quoted as only considering the stress normal to the plane of maximum shear

Hancock[36, 38, 43, 46, 55] first tested solid steel rounds, and then steel tubing, in tension and torsion. His results have been adversely criticised, and certainly supported neither hypothesis, although the author favoured the shear stress theory. Later tests under tension or compression with torsion indicated that the maximum tension was seldom greater than the tensile strength of the steel, but the maximum shear stress was often greater than its shearing strength.

Izod[37] tested materials to fracture in double shear. The discussion on his paper makes it clear that shearing tests of this type are complicated by cross stresses after yield. The ratio of shear to tensile strength was 0·62 to 0·78 for iron and steel, the tensile strength being the maximum load divided by the original area of the cross-section. The results were confirmed by Goodman. Lilly held the surprising view that only under exceptional conditions was the shear strength less than the tensile, and that isotropic materials were strongest in compression, next in pure shear and weakest in tension. There was a rough indication that ductile materials followed the shear rather than the maximum stress law of failure.

Frémont[39] modified the usual shearing test by filing away the sheared face from time to time to eliminate the friction between the steelings and the sheared faces. He then found that the shear stress at fracture was about 0·4 times the maximum tensile stress for irons and steels which had a range of tensile strength from 19 to 65 tons per square inch.

Scoble[40, 61] employed combinations of bending and torsion on solid round steel bars. Yield was taken as the point of failure. The maximum shear stress varied from 29,170 to 33,500, and the maximum principal stress from 29,170 to 64,600 lb. per square inch, having the low values in pure torsion. The bending moment was not constant over the length of a bar, which would tend to mask the yield and give a high stress under bending. It was concluded that the maximum shearing stress was approximately constant at yield, but it was also shown that engineering materials are not perfectly isotropic, and consequently have different shearing strengths in different directions. Later tests included steel and

copper tubes subjected to torque and a uniform bending moment. The maximum shear stress again varied, being greater in bending than in torsion, but this deviation from the law is in the contrary direction to that required by Theories (*a*) and (*b*).

Turner's[50, 69] early experiments were modelled on those of Guest. He tested steel tubes in simple tension, and under simple torque, and included a few tests under combined tension and internal pressure. The shear stress theory was confirmed at elastic breakdown. Later he made a few experiments with solid mild, tool, and nickel steels in simple tension and torsion. The maximum shear stresses were · for mild steel 21,200 and 24,400, tool steel 33,900 and 38,400, and for nickel steel 40,600 and 40,800 lb. per square inch. He says: 'It is clear that the shear theory is no general law which covers all elastic materials. The tool steel shows the greatest inequality of shear in the two distributions of stress; yet even for it the theory that failure occurs through shear is obviously very much closer than the tension hypothesis.'

Three-dimensional stress was secured by the use of thick steel cylinders under internal pressure and longitudinal tension. The tubes were so thick that the radial compressive stress was usually about 11,000, but in one case reached 17,200 lb. per square inch. The principal stresses were two tensions and one compression. The external diameter of the cylinder decreased at yield. For one tube the extreme value of the maximum shearing stress were 16,600 in simple tension, and 20,900 under simple torque. He deduces from these experiments that the shear theory is not very far from true, but that it is sensibly untrue. The tube was used for several tests with intermediate annealing. The maximum shear stress for one test in simple tension was 18,500 lb. per square inch.

Smith[54, 59, 60, 68] tested solid steel specimens in tension or compression with torsion. He supported Theory (*c*). Experiments with non-ferrous metals demonstrated the attendant difficulties and did not lead to satisfactory results.

Mason[58] extended the range of conditions by testing steel tubes in tension, compression, compression and hoop tension, compression and hoop compression. His experimental results show an approximate agreement between the maximum shear stress at the yield point in compression, and the yield point stress in pure shear (obtained by equal tensile and compressive principal stresses), the mean difference in the tests of annealed specimens being about 3 per cent. 'It appears, then, that mild steel in direct compression yields by shearing; and to a first approximation that the value of this shear stress is independent of any normal compressive stress on the planes of the slide.' The direct application of two compressive principal stresses to steel was an important advance.

Cook and Robertson[73] determined the strength of thick hollow cylinders of cast iron and steel under internal pressure. They concluded that the failure of cast-iron cylinders is determined solely by the maximum principal stress, and for mild steel cylinders the pressure is about 20 per cent. in excess of that required by the shear stress theory, or midway between that indicated by Theories (*b*) and (*c*).*

* These results differ from those of other observers. Cast-iron cylinders fractured according to the formula based on the principal stress law, but since this formula applied also to the steel cylinders, there is no proof here that cast iron fractures

Bridgman[74, 75] worked with extremely high-fluid pressures applied to the curved surface of a rod of circular section, on the outside of plugged hollow cylinders, and to the inside of heavy cylinders. All tests were to rupture. Brittle materials were also tested. Little numerical data is given. The original paper should be consulted since it does not lend itself to abstraction, and the results are very remarkable. It is doubtful whether the deductions, that all the theories of strength are not valid under certain conditions, are justified by these experiments.

9. *Brittle Materials under Combined Stresses.*

Carus Wilson[20] found the tensile strength of cast iron to be 10·4, and the shearing stress at fracture to be 5·46 tons per square inch, ratio 1·9. Platt and Hayward found the ratio to be 2·2. The mean crushing strength was 41·5 tons per square inch. The rupture of cast iron in compression by shearing is well known, and he appeared to consider that it also held for tension.

Izod[37] gives the ultimate shear stress of cast iron from 1·1 to 1·5 times the ultimate tensile strength.

Scoble[41, 64] fractured round cast-iron bars by combined bending and torsion. The calculated stresses followed neither law, but the angles of fracture agreed well with the planes of maximum principal stress. On the assumption of a redistribution of stress by yield the maximum principal stress varied 10 per cent. on either side of the mean value. Hardened cast-steel bars were elastic to fracture. At least two tests were made on each bar. The maximum principal stress was nearly constant at fracture for each bar, and the bar broke along the plane of maximum principal stress with extreme accuracy.

Williams[42] attempted to determine the effect of fluid pressure on the strength of rock salt and hard aluminium. He claimed to disprove the Poncelet Theory, but the range of the experiments was too limited to draw further conclusions.

Grübler[51] used cement mortar formed round a central shaft and covered by a clamp which carried torsion levers. The shear stress was the same at all points at the same distance from the axis. The cement failed by tension, but never by shearing.

Kármán[71] compressed marble and sandstone and supplied latera pressure by means of glycerine under pressure. He quotes Mohr's Law as the shear stress law. With no side pressure these stones behave as brittle materials, but with a pressure of 700 atmospheres the material becomes perfectly plastic, and the elastic limit is raised. Further deformation is possible after the elastic limit if the lateral pressure is increased, but the effect is rapidly diminished at high pressures. The stones flowed on planes at 45 degrees to the axis. Permanent set may take place by relative shearing of the crystals for low values of the lateral pressure, or by internal changes in the crystals at high values. The first kind of failure occurs at a maximum value of the shear stress which depends on the normal stress, but the second form takes place at a limiting constant shear stress, and the material hardens.

according to Theory (*a*). The results for steel are ratios depending on the tensile strength, and would be high unless the first yield was detected. Their cylinders increased in diameter at yield, Turner's diminished.

Adams,[62] and *Nicholson*,[30] and *Coker*[65] tested rocks in compression, and supplied lateral support by enclosing each specimen in a steel cylinder which bulged laterally. Marble flows as a plastic body under differential pressure by distortion of the calcite grains, and the deformed specimen retains 60 to 85 per cent. of its original compressive strength. Its specific gravity is not increased. By Kick's process—in which the specimen is embedded in a fused salt, usually alum, to fit the retaining cylinder—minerals with hardness under 5 show plastic deformation, which is less pronounced as they are harder. Still harder minerals, which do not flow, have their structure broken down and are powdered. Fine-grained, massive limestones show combined flow and fracture. Harder rocks, like granite, crumble under pressure, but the flow structure is developed in these by greater differential pressures.

10. *The Friction Theory.*

Many investigators have studied the internal friction of solids, and when not associated with combined stresses the favourite method has been by the decay of torsional oscillations. Only a few references are given to the large volume of research of this type. Lord Kelvin[19] pointed out that the damping was caused by all the effects included under the class of hysteresis phenomena. Bouasse dealt with torsional oscillation, and paper No. 32 includes a review of his work. Ercolini[49] again pointed out that the damping is due to hysteresis, and not to molecular friction. Guye's work is of a similar character.

Reference has been made to the angles of fracture of brittle materials in compression, which probably suggested Theory (*d*), and to the equality of the yield stresses for steel in tension and compression.

In connection with combined stresses, Scoble[40, 61] considered that the friction theory does not apply to steel. Gulliver[47] found that steel yields in tension at an angle of 50 degrees to the axis ($\mu = 0{\cdot}176$), but this is not confirmed by yield at 40 degrees in compression. A study of combined stress experiments led him to the same conclusion as that of Scoble, since calculated values of 'μ' varied from $-0{\cdot}242$ to $0{\cdot}38$. Smith's[54] tests did not support the friction theory for steel, nor did those of Mason[58] which were specially well adapted to test it.

11. *Lüder's or Hartmann's Lines.*

These markings have been studied in this country chiefly by Gulliver[34, 67] in relation to the friction theory, and by Mason[70] in connection with his combined stress experiments. Their papers will furnish further references.

12. *Some other Considerations in Combined Stress Researches.*

The peculiarities in the behaviour of steel—variation of the elastic limit, hysteresis, &c.—have been discussed elsewhere. It is possible that their importance has been magnified, since the elastic limit and yield point coincide approximately for thoroughly annealed steel, and the hysteresis effect is extremely small. The difficulties are intensified in the case of other metals, because most have no elastic range and no well-defined yield. Apparently we must study the fracture of these materials under uniform stress distribution. Brittle substances, like rocks, cement, &c., are

probably simpler to deal with than non-ferrous metals, or even cast iron, to a first approximation; but Bauschinger found that the strength of stone varies considerably with the proportions of the specimens,[12] and that stone has no elastic limit, taking sets with small loads.[11] Hard and dense stones are better in these respects, and all are better at higher loads. The difference in the strength of some rocks in different directions is very great. Nagaoka[25] also found rocks to be very imperfectly elastic, but Adams and Coker[65] consider their elasticity in compression to be better than that of cast iron, especially after they are loaded several times to attain a state of ease.

The errors which are likely to be introduced in tests of rocks in compression are now well known, and the best-conducted tests leave some uncertainty regarding the true compressive strength.[26]

It is impossible to deal fully here with the behaviour of the crystals in a material under stress. The researches of Ewing and Rosenhain are well known, and those of Beilby deserve notice. The discussion on the papers of Mason and Smith[58] included a reference to this matter by Gulliver, and a most suggestive contribution from M. Osmond.

Papers which deal with experiments made on rocks usually refer to the behaviour of the separate crystals.

13. *Alternating Combined Stresses.*

The only experiments with which we are acquainted which have been intended directly to investigate alternating combined stresses are those of Turner.[69] The plan of the research was not all that could be desired, but was probably the best that could have been done with the available facilities. Specimens were tested under alternating bending and torsion, but not combined. The torsion was taken as an example of combined stresses. The chief results are shown in the table.

Material	Tube Steel	Mild Steel	Tool Steel	Nickel Steel	—
	lb./sq. in.	lb./sq. in.	lb./sq. in.	lb./sq. in.	
Elastic Limit . .	31,000	42,300	67,000	81,200	Tension by bending
Endurance . .	29,000	40,000	50,000	59,000	
Elastic Limit . .	17,000	24,000	38,400	40,800	Shear
Endurance . .	16,000	22,000	38,000	35,000	
Per cent. Elong. (8)	24	29	9	14	At fracture

The tube and mild steel specimens conformed to the shear stress law under alternating stresses. The tool steel was particularly weak in alternating tension, and with nickel steel the drop in strength was greater in tension than under torsion. The percentage elongations indicate that the more ductile steels obey the shear stress law under repeated loadings, and the behaviour of the more brittle samples approaches more closely to that required by the maximum strain and maximum stress theories.

Wöhler tested steels under repeated tension and compression, bending, and torsion. It is difficult to compare his results for our purpose, since there were considerable differences in the material included under the same title—the elongation at fracture for Krupp's cast steel for axles varied from 11·7 to 23·7 per cent. The range of stresses which he selected from all his tests probably refer to an average sample, and these for cast steel

axles are under tension, compression, or bending 13·38 to −13·38, range 26·76; 23 to 0, range 23. Shearing or torsion 10·5 to −10·5, range 21. 18·2 to 0, range 18·2. These figures would approximately fit the maximum strain theory. It is evident that more work is required in this portion of our field.

14. *The Separation of Materials.*

A distinction has been drawn between ductile and brittle materials. *Frémont*[28] has arrived at the interesting conclusion that steel is brittle or tough according to whether the ratio of the elastic limits in tension and compression is less or greater than one. It is quite possible that the usual classification is not along correct lines, and this should be discovered when greater attention is paid to substances of an intermediate character. The latter appear likely to introduce considerable complexity. For completely ductile and brittle materials it appeared possible that double limits would cover all the conditions, and these would be shear modified by friction, and possibly the maximum stress in tension. The intermediate steels appear to show an intermediate behaviour, and then we cannot apply the two limits. Scoble[61] has suggested that a criterion might be found of the form

$$P_1 + mP_3 = c$$

in which m depends on the degree of ductility of the material. This equation is a general expression for all the laws except that of maximum strain, which would require a P_2 term. For brittle materials m and c have different values in tension and compression. A microscopic study is particularly desirable to discover the mechanism of failure for the intermediate materials, since it is possible that it is not of a simple character, but a combination of that exhibited by the extremes. It is further necessary to give each substance its correct position in a scale based on those standard properties which determine its behaviour under combined stresses.

15. *An Engineering View.*

Yield has been taken to denote failure in most tests of ductile materials under compound stress. The reason has sometimes been given that the yield stress, and of course certain other considerations, fixes the working stress. This is only partly correct; the ultimate strength retains much of its old importance, and the relative bearing of the yield and maximum stresses depends on the conditions of the case under consideration. The real reason for the selection of the yield point appears often to have been, either that the scheme of the tests was such that they could not conveniently be continued to fracture, or that the stress distribution varied from point to point and could be estimated only within the elastic range.

Although a knowledge of the 'Law of Failure' is of great interest, it is not of great importance to the engineer in cases of simple static loading. He will prefer to fix his working stresses by tests which are modelled on the working conditions. When combined stresses are produced by the loading, the theories are liable to be misleading or of no assistance. Two examples will illustrate this contention.

The yield and maximum stresses are considered to fix a working stress for a sample of steel in tension. The yield stress should not be exceeded, and the excess of the maximum over the yield stress is a reserve of strength.

The experiments which have been recorded indicate that a plain shaft subjected to combined bending and torsion should be designed for an equivalent torque, $\sqrt{M^2 + T^2}$. The maximum stress theory gives $M + \sqrt{M^2 + T^2}$. The latter emphasises the importance of the bending moment, and bending yield is much more serious than torsion yield. A small bending yield would cause a considerable deflection of the shaft, but a twist would fully stress more material with a strain of little importance. It is not at all clear that the formula which gives the equivalent torque to cause yield is the best for the purposes of design. The results of the repeated loading tests, at least for the harder steels, lend further support to this view.

The important cases of combined stresses in practice are usually accompanied by a variable stress distribution. We may assume that the shear stress theory will allow the load at yield to be calculated, but the engineer requires to know the fracture load to estimate the reserve of strength. Bridgman [74, 75] states he found that he could raise the yielding pressure of a thick cylinder under internal pressure tenfold by giving it a set. The reserve strength here is not only due to the difference between the yield and maximum stresses, but also to the understressed material. A law of failure does not help an engineer to calculate to fracture in many such cases, and he must depend on experiments made under the conditions of each case.

The above considerations point to the advisability of confining tests on ductile steels to the elastic limit or yield point, and of considering the importance of tests to fracture in cases of 'Special Problems' which involve complex stress distributions.

16. *Conclusion.*

Most experimental work has been done on ductile steel, but more tests are required under three-dimensional stress, and particularly under compressive stresses.

One point appears to have escaped notice. A material might appear to have different shearing strengths under different systems of stress, as in the case of cast iron in shear and under compression. The shearing stress has been shown to be approximately constant at the elastic failure of steel under modification of the same general type of stress distribution. Are these maximum shearing stresses the same under all conditions of loading?

They have frequently been compared with the tensile strength, and the differences do not seem to be great, but it would be of interest, and necessary for further refinement, to test exactly the same material under very different combinations of principal stresses.

Few experiments have been made with the materials now classed as brittle, and those already made should mostly be repeated. Here we can assume that there is a clear field. The same applies to non-elastic ductile metals, and to those intermediate between ductile and brittle.

The methods of experiment will require further consideration. Simple tension and compression are the most direct tests available. Longitudinal tension and internal fluid pressure applied to a thin hollow cylinder appear to be the readiest means of securing two tensions. Longitudinal compression and external fluid pressure have been used

for obtaining two compressions, but it is hardly satisfactory for all cases, and might be replaced by external fluid pressure on a solid specimen with free ends, as in Bridgman's pinching-off test, but this requires extremely high pressures. A complete treatment of the problem in three dimensions appears possible only by the use of high-fluid pressures.

Cases of combined stresses in engineering practice should be the subjects for separate tests, and cannot entirely replace those which are intended to determine the laws of failure. Combined alternating stresses are mainly of practical interest, and here again the experiments should be modelled to suit the engineering examples. Cases are not uncommon in which compound stresses are applied under shock conditions, but a further consideration of this matter might well be the subject for a later report.

Bibliography on Combined Stress.

1	Coulomb	1776	Essai sur uno application de règles de Maximis et Minimis à quelques Problèmes de Statique, relatifs à l'Architecture. 'Mém. par divers Savants,' 1776.
2	Vicat	1834	Note sur l'allongement progressif du fil de fer soumis à diverses tensions. 'Annales des ponts et chaussées,' 1er semestre, 1834.
3	Mariotte		Traité du mouvement des eaux, sixième et troisième alinéa du second discours.
4	Lamé	1833	Mémoire sur l'Equilibre intérieur des corps solides homogènes. Paris, 'Mém. par divers Savants,' t. 4, 1833.
5	Poncelet	1839	See 'Todhunter and Pearson's History.' Vol. i. 995.
6	St. Venant		Historique Abrégé in St. Venant's edition of the 'Leçons de Navier,' pp. cxcix–ccv.
7	Wertheim	1848	Determinations of Poisson's Ratio. 'Annales de Chimie,' t. 23, 1848.
8	Hodgkinson, E.	1857	Experimental Researches on Cast-Iron Pillars. 'Phil. Trans. Roy. Soc.,' 1857.
9	Tresca, H.	1868	Flow of Metals.
		1872	'Mém. par divers Savants,' 18, 1868.
		1878	Ditto, 1872. 'Proc. I.M.E.,' 1878. See also 'Comptes Rendus.'
10		1870	Experiments on the Mechanical and other Properties of Steel. By a Committee of Civil Engineers, 1870. Also Unwin's 'Strength of Materials.'
11	Bauschinger	1875	Ueber den Elasticitats-Modul Baustein. 'Mitt. aus dem Mech. Tech. Lab. München,' 1875. Also Unwin's 'Strength of Materials.'
12	Bauschinger	1876	'Mitt. aus dem Mech. Tech. Lab.,' 1876.
13	Darwin, G. H.	1882	Stresses produced in the Interior of the Earth by the Weights of Continents and Mountains. 'Phil. Trans. Roy. Soc.,' 173, 1882. Kelvin and Tait, 'Nat. Phil.,' II., Art. 832.
14	Chree, C.		'Transactions Cambridge Phil. Soc.,' vol. xiv., Part III., p. 273.
15	Appleby, P. V.	1883	Iron and Steel in Tension, Compression, Bending, Torsion and Shear. 'Proc. I.C.E.,' vol. lxxiv.
16	Kirkaldy	1884	Iron and Steel in Tension, Compression, Bending, Torsion and Shear. 'Proc. I.C.E.,' vol. lxxvi.
17	Platt and Hayward	1887	Experiments on the Strength of Iron and Steel in Shear and Torsion. 'Proc. I.C.E.,' vol. xc.
18	Wehage	1888	On the Critical Extension of Bodies strained simultaneously in Several Directions. 'Mittheil. aus den Königlichen techn. Versuchsanstalten zu Berlin,' 1888. 'Proc. I.C.E.,' 95, p. 410, Abstract.

19		1890	Article 'Elasticity.' 'Encyc. Brit.,' or 'Math. and Phys. Papers,' vol. iii., 1890, or see Lamb's 'Mathematical Theory of Elasticity,' 1906, p. 115.
20	Wilson, C.	1890	'Proc. Roy. Soc.,' vol. xlix., March 1890, and 'Phil. Mag.,' June 1890.
21	Föppl, A.	1899	'Mittheilungen (München),' xxvii., 1899.
22	Föppl, A.	1899	The Relation of Failure to the Manner of Application of Stress. 'Centralblatt der Bauverwaltung,' 1899. Abstract in 'Proc. I.C.E.,' vol. cxl.
23	Guest, J. J.	1900	On the Strength of Ductile Materials under Combined Stress. 'Phil. Mag.,' July 1900. 'Phys. Soc. Proc.,' vol. xvii., Sept. 1900.
24	Mohr, O.	1900	'Zeitschrift Ver. Deutschen Ing.,' Bd. 44, 1900.
25	Nagaoka	1900	The Elastic Constants of Rocks, &c. 'Phil. Mag.,' 1900.
26	Martens, Föppl and Berner	1899 1900	The Relation of Failure to the Manner of Application of Stress. 'Centralblatt der Bauverwaltung,' 1899, p. 590; 1900, p. 147.
27	Voigt	1901	Theory of Solids. 'Ann. Phys.,' Ser. 4, March 1901.
28	Frémont, C.	1901	Relation between Brittleness and Elastic Limits for Tension and Compression. 'Comptes Rendus,' 132, Jan. 28, 1901.
29	Coker, E. G.	1901	Iron and Steel under Torsional and Combined Stress. 'Roy. Soc. Edinburgh Trans.,' 40, Nov. 12, 10, 1901.
30	Adams, F. D., and Nicholson, J. T.	1901	An Experimental Investigation into the Flow of Marble. 'Phil. Trans. Roy. Soc.,' Series A, vol. cxcv.
31	Filon, L. N. G.	1902	Elastic Equilibrium of Circular Cylinders under certain Practical Systems of Load. 'Roy. Soc. Phil. Trans.,' 198, Feb. 28, 1902.
32	Bouasse, H.	1903	Deformation of Solids. 'Annal. Chim. Phys.,' 29, July 1903.
33	Obermeyer, Tammann, Werigin, Lewkogiw	1905	Flow of Solids. 'Beiblätter Annal. Phys.,' vol. 29, 1905.
34	Gulliver, G. H.	1905	Permanent Deformation of Metals. 'Proc. I.M.E.,' Jan., Feb. 1905.
35	Wehage, H.	1905	Stresses in Materials simultaneously loaded in Several Directions. 'Zeitsch. Ver. Deutsch. Ing.' 49, July 1, 1905.
36	Hancock, E. L.	1905	The Effect of Combined Stresses on the Elastic Properties of Steel. 'Eng. News,' 54, Aug. 24, 1905.
37	Izod, E. G.	1906	Behaviour of Metals under Shear. 'Engineering,' Dec. 22, 1905. 'Proc. I.M.E.,' Jan. 1906.
38	Hancock, E. L.	1906	The Effect of Combined Stress in Iron and Steel. 'Phil. Mag.,' 12, October 1906.
39	Frémont, C.	1906	Shear Strength of Structural Materials. 'Soc. d'Encour. Rev. de Métall.,' 3, July 1, 1906.
40	Scoble, W. A.	1906	The Strength and Behaviour of Ductile Materials under Combined Stress. 'Proc. Phys. Soc.,' xx., and 'Phil. Mag.,' Dec. 1906.
41	Scoble, W. A.	1907	The Strength and Behaviour of Brittle Materials under Combined Stress. 'Proc. Phys. Soc.,' xx., Jan. 1907.
42	Williams, W. E.	1908	Rupture of Materials under Combined Stress. 'Phil. Mag.,' Jan. 1908.
43	Hancock, E. L.	1908	The Effect of Combined Stress on Steel. 'Phil. Mag.,' Feb. 1908.
44	Bouasse, H. Carrière, Z.	1908	Decay of Oscillations. 'Annal. Chim. Phys.,' 14, June 1908.
45	Smith, C. A.	1908	Guest's Law on Combined Stresses. 'Engineering,' July 10, 1908.

46	Hancock, E. L.	1908	The Behaviour of Metals under Combined Stress. 'Phil. Mag.,' Nov. 1908.
47	Gulliver, G. H.	1908	The Cohesion of Steel and Relation between the Yield Points in Tension and Compression. 'Proc. Roy. Soc. Edin.,' 28, 1908.
48	Gulliver, G. H.	1908–1909	Internal Friction in Cases of Compound Stress. 'Proc. Roy. Soc., Edin.,' 29, 1908–09.
49	Ercolini, G.	1909	Recent Experiments on Elasticity. 'N. Cimento,' 17, Jan. 1909.
50	Turner, L. B.	1909	The Elastic Breakdown of Materials under Combined Stress. 'Engineering,' 87, Feb. 5, 1909.
51	Grübler	1909	Shear Strength and Elasticity. 'Zeitschr. Ver. Deutsch. Ing.,' 53, March 20, 1909.
52	Coker, E. G.	1909	Testing Machine for Combined Bending and Torsion. 'Phil. Mag.,' April 1909.
53	Poynting, J. H.	1909	Pressure Perpendicular to Shear Planes and Lengthening of Wires when Twisted. 'Proc. Roy. Soc.,' A, 82, July 1909.
54	Smith, C. A.	1909	Solid Steel Bars under Combined Stress. 'Engineering,' 88, Aug. 20, 1909.
55	Hancock, Ed.	1909	Design in Case of Combined Stress. 'Eng. News, 62, Sept. 2, 1909.
56	Guye, C. E. Friedericksz, V.	1909	Internal Friction of Solids at Low Temperatures. 'Comptes Rendus,' 149, Dec. 6, 1909. See also Guye and Mintz, 'Arch. des Sciences,' 26, 1908. Guye and Schaffer, 'Comptes Rendus,' 150, April 1910.
57	Schulze, F. A.	1909	Relation between the Elastic Modulus, Tension, Torsion and Strain. 'Ann. d. Physik,' 31, Dec. 30, 1909.
58	Mason, W.	1909	Mild Steel Tubes in Compression and under Combined Stress. 'Proc. I.M.E.,' 4, 1909.
59	Smith, C. A. M.	1909	Compound Stress Experiments. 'Proc. I.M.E.,' 4, 1909.
60		1909	The Elastic Breakdown of Non-Ferrous Metals. 'Inst. Metals Journ.,' 2, 1909.
61	Scoble, W. A.	1910	Ductile Materials under Combined Stress. 'Proc. Phys. Soc.,' vol. xxii. 'Phil. Mag.,' Jan. 1910.
62	Adams	1910	Differential Pressures on Minerals and Rocks (Kick's Process). 'Journ. of Geology,' Sept., Oct. 1910.
63	Morley, A.	1910	Strength of Materials under Combined Stress. 'Engineering,' April 29, 1910.
64	Scoble, W. A.	1910	Further Tests of Brittle Materials under Combined Stress. 'Proc. Phys. Soc.,' vol. xxii. 'Phil. Mag.,' June 1910.
65	Adams, F. D. Coker, E. G.	1910	Experiments on the Flow of Rocks. I. The Flow of Marble. 'Am. Journ. Sci.,' 29, June 1910.
66	Turner, L. B.	1910	Stresses in a Thick Cylinder subjected to Internal Pressure. 'Camb. Phil. Soc. Trans.,' 21, No. 14, Sept. 12, 1910.
67	Gulliver, G. H.	1909 1910	A New Experimental Method of Investigating Certain Systems of Stress. 'Proc. Roy. Soc. Edin.,' 30, 1909–10.
68	Smith, C. A. M.	1910	The Elastic Breakdown of Certain Steels. 'Iron and Steel Instit. Journ.,' 1910.
69	Turner, L. B.	1911	The Strength of Steels in Compound Stress and Endurance under Repetition of Stress. 'Engineering,' July 28, 1911.
70	Mason, W.	1911	Lüder's Lines on Mild Steel. 'Phys. Soc. Proc.,' 23, Aug. 1911.
71	Kármán, T. V.	1911	Compression Tests of Marble and Stone. 'Zeits. Ver. Deutsch. Ing.,' 55, Oct. 21, 1911.
72	Houstoun, R. A.	1911	A Relation between Torsion and Tension. 'Phil. Mag.,' Nov. 1911.

73	Cook, G. Robertson, A.	1911	The Strength of Thick Hollow Cylinders under Internal Pressure. 'Engineering,' 92, Dec. 15, 1911.
74	Bridgman, P. W.	1912	The Collapse of Thick Cylinders under High Hydrostatic Pressure. 'Phys. Rev.,' 34, Jan. 1912.
75		1912	Breaking Tests under Hydrostatic Pressure and Conditions of Rupture. 'Phil. Mag.,' July 1912.
76	Basquin, O. H.	1912 1913	The Circular Diagram of Stress and its Application to the Theory of Internal Friction. 'West Soc. Eng. Journ.,' 17, Nov. 1912. 'Sci. Abs.,' Feb. 1913, No. 149.
77	Mallock, A.	1912	Some Unclassified Properties of Solids and Liquids. 'Proc. Roy. Soc. A.,' Dec. 1912.
78	Mallock, A.		The Extension of Cracks in an Isotropic Substance. 'Proc. Roy. Soc.,' A, vol. 82, pp. 26–29.
79		1912	The Yield Point and the Elastic Limit. 'Engineering,' Jan. 26, 1912. Definitions by the Engineering Standards Committee and Recommendation of the Ships Committee.
80			Report on 'Theories and History.' Also Applied Mechanics, Perry.

Report on Alternating Stress. *By* W. Mason, *M.Sc., with Notes by* F. Rogers, *D.Eng., and* E. M. Eden.

Index.

Introductory.

By an 'alternating stress' is meant a stress varying cyclically between maximum and minimum values. Unless otherwise stated, it is implied that the stresses are imposed without shock, and that the variation of stress on either side of the algebraic mean of the maximum and minimum stresses is, or is approximately, simple-harmonic. The range of stress is the algebraic difference between the maximum and minimum stresses.

The resistance of a material to alternating stress may be measured by the values of the maximum and minimum stresses of the cycle whose

repetition for some particular very large number of times will just produce fracture. If unlimited time were available for testing, the very large number referred to would be indefinitely great or would exceed the number of repetitions which the material would be required to withstand in service.

The cycle of stress having its maximum and minimum respectively of equal (or nearly equal) positive and negative values is the most important practically; and the bulk of experimental work has been done with this cycle. The usual method of finding experimentally the resistance of a material is to make a number of tests to destruction with a series of ranges of stress of this (equal ±) cycle; the first of the series having an appropriate high range, and subsequent series a successively less and less range. This succession of tests is continued until the number of the repetitions before fracture is at least a million. Plotting the ranges of stress, '*f*' (or half the range of the cycle of equal + and − stresses), against the respective number of repetitions, '*n*,' before fracture, an '*f*, *n*' curve, or 'endurance curve,' is obtained. This curve (at any rate for iron and steel) becomes less and less inclined to the axes of '*n*' as '*n*' becomes larger. Where the curve becomes sensibly asymptotic to a line parallel to the axis of '*n*,' the ordinate—*i.e.*, the range of stress—between the asymptote and the axis of '*n*' is called the 'limiting range,' or the 'Wöhler safe range.' This range is a definite measure of the 'endurance' under the type of stress and conditions of test. The term 'endurance' has been somewhat loosely used, and it is not employed herein to denote any particular measure of the resistance to alternating stress.

Testing Machines.

The machines used in making the alternating stress tests that have been published are referred to in the bibliography and the notes contained therein.

Data from Published Tests.

It has been suggested * that a list of all published data of tests should be made out. Such a list should include (if available) information concerning the chemical composition, manufacture, previous heat treatment, testing machine, shape and preparation of specimen, and an attempt to estimate how nearly the Wöhler safe ranges have been approached in each case. This matter is one of some magnitude, and is at present left over for further discussion.

Bauschinger's Theory.

This theory is thus concisely stated by Bairstow (No. 2,† page 168, Vol. VI. 'Collected Researches,' N.P.L.) :—'The superior limit of elasticity can be raised or lowered by cyclical variations of stress, and at the same time the inferior limit of elasticity will be raised or lowered by a definite, but not necessarily the same, amount. The range of stress between the two elastic limits has therefore a value which depends only on the material and the stress at the inferior limit of elasticity. This elastic range of stress is the same in magnitude as the maximum range of stress which can be repeatedly applied to a bar without causing fracture, no

* By Prof. J. E. Petavel.

† The numbers refer to the bibliography of this Section.

matter how great the number of repetitions. Bauschinger made experiments to show that these definitions did not apply to the elastic limits as measured on a previously unstrained specimen, and he made experiments to show that the elastic limits in this case, which he called primitive elastic limits, were unstable, and that only a few reversals of stress were necessary to produce a condition in which the theory was satisfied. In this latter state Bauschinger defined the elastic limits as "natural elastic limits."'

It is interesting, here, to note that the ideas underlying Bauschinger's theory had been published so long ago as 1848 by James Thomson *; who wrote: there are 'two elastic limits for any material, between which the displacements or deflexions, or what may in general be termed changes of form, must be confined, if we wish to avoid giving the material a set, or in the case of variable strains, if we wish to avoid giving it a succession of sets which would bring about its destruction;' . . . these limits 'may therefore, with propriety, be called the superior and the inferior limit of the change of form of the material for the particular arrangement which has been given to its particles; that these limits are not fixed for any given material, but that, if the change of form be continued beyond either limit, two new limits will, by means of an alteration in the arrangement of the particles of the material, be given to it in place of those which it previously possessed.'

There is now no doubt concerning the existence, for iron and steel, of elastic ranges such as those found and actually measured by Bairstow. Provided that these ranges, when once attained, are never exceeded, it may be regarded as quite certain that any number of cycles of any speed of alternation can have no destructive effect. (See Article 'Elastic Hysteresis' of this Report.) But in most cases, certainly with cycles of unequal $\pm$ stresses, and most probably with equal $\pm$ stresses, the elastic range is reached through a partially elastic period which is gradually ended by recovery and the attainment of elastic limits adjusted to the range of stress. Though it is improbable that these elastic ranges can be affected, either in range or position of range, by speed of alternation, yet it seems quite certain that the duration of the period and the number of cycles necessary for the adjustment may be very largely influenced by this speed (No. 43). It is not so certain that the range of adjustment does not depend on the temperature of testing; but experimental evidence on this point is wanting. Thus it is not quite certain that the elastic ranges found by Bairstow would have been exactly the same if the temperatures of his experiments had been different.

Mr. Bairstow's method of finding the values of the elastic ranges from his observations is one that leaves a little room for personal judgment; but since he estimates the probable error of this process to be within half a ton per square inch, it is clear that the elastic ranges found were quite definite.

The identity of these elastic ranges with the limiting safe ranges of fatigue tests can hardly be said to be conclusively proved. But there is considerable evidence in favour of it, and it appears to the writer that this identity may be regarded as sufficiently well established.

The term 'natural' elastic limit is in certain respects a little misleading. A piece of material of a definite composition and crystalline structure will

* *Cambridge and Dublin Mathematical Journal.* The paper is quoted by Kelvin in his Article 'Elasticity,' *Ency. Brit.*, 9th ed. vol. vii., p. 800, § 19, but does not appear to be generally known; it has recently been pointed out by Prof. J. Perry.

certainly possess 'natural' elastic limits when it has been subjected to a number of repetitions of stress of approximately the amount of the limiting range; and it has been shown by Bairstow that a limit exists above which the tension elastic limit cannot be raised, so long as the stress is entirely removed in each cycle. The piece *may* possess natural elastic limits when the process of overstrain and recovery attempted by Bauschinger, and carried out with more (though not complete) success by Bairstow, has been applied to it. It has not yet been proved that the natural elastic limits for equal $\pm$ stress cycles are the same as would be found in static tension and compression by the use of an exceedingly delicate extensometer on the piece in its primitive state. The question has not been definitely settled whether, when the primitive elastic limits have been altered, and the granular structure distorted, by cold working, the natural elastic limits will or will not remain the same; though it is certain that the part of the f, n curve for small values of n will be made to fall above the corresponding part of the curve for the unworked stuff. It appears from the Table, Appendix II., that the annealing to which the specimens of published repeated stress tests have been subjected produces, in general, some little lowering of the 'natural' elastic limits; though the primitive elastic limits may be very much altered by this heat treatment.

There appears to be no definite relation between the 'natural' elastic limits and either the primitive elastic limit, the yield point or the ultimate tensile stress.

Recovery of Elasticity.

It is a well-known fact, discovered by Weber in 1835, that 'when a body is strained beyond the elastic limit and is set free, part of the strain disappears at once, and the strain that does not disappear gradually diminishes. The body never returns to its primitive condition, and the ultimate deformation is the permanent set; the part of the strain that disappears is called elastic after-strain.'* In the case of the metals of engineering construction, the immediate re-application of the stress after such overstrain shows the metal to be in an imperfectly elastic state; but if the stress be re-applied after a considerable period of rest, during which the elastic after-strain disappears, the elasticity is found to be restored. The period of rest may be shortened to one of a few minutes only, if the temperature be raised to 100° C.; presumably the elastic after-strain disappears in this short interval, though, so far as the writer is aware, this has not been verified experimentally. After this recovery the elastic limit is somewhat higher than at the first overstraining. Provided the recovery is complete, further exposure to this temperature, or to considerably higher temperature in the case of many metals, produces no further effect; and the additional exposure has no more effect than on a piece of the unstrained material.

It may be noticed here that the limit of proportionality of wrought iron is practically the same at 0° C. and 250° C., there being some little variation between these temperatures with a maximum about 200° C.†

It has been proved that, in general, non-elastic strain is effected by cleavage plane slipping in the crystalline grains. The parts of a crystal not immediately contiguous to the slipped surfaces are, so far as can be

* Quoted from Love's *Theory of Elasticity.*
† A. Martens, *Proc. Inst. C.E.*, vol. civ.

detected under the microscope, unaffected by plastic strain.* The effect of the increase of temperature which promotes recovery of elasticity must therefore be upon the material which, according to Beilby,† exists in an altered physical and perhaps molecular condition between the slipped surfaces; or, at any rate, upon material in the immediate neighbourhood of these surfaces.

Recovery, then, is due to the effect of temperature on this material, resulting in the healing up of the crystalline slips. It seems reasonable to suppose the disappearance of 'elastic' after-strain to be a phase of this healing process, rather than a distinct and different phenomenon. The fact that recovery is much impeded or totally stopped in the case of iron and steel at a temperature of 0° C. shows that rest, unless accompanied by a suitable temperature, is ineffective in promoting restoration of elasticity; the rapidity of recovery—*i.e.*, the duration of rest required—being thus a function of the temperature.

Turning now to the consideration of cyclically applied stresses, Ewing has remarked:‡ 'When in the overstrained condition, and before recovery has taken place, iron and steel exhibit much hysteresis in the relation of extension to load. Any process of loading and unloading, repeated until the changes become cyclic, then shows a well-marked difference in the length of the piece for any one amount of load in the two stages of the process. The curves exhibiting extension in relation to load form a loop, and this loop closes up as the piece gradually recovers its elasticity by prolonged rest.' Recovery of elasticity may thus be defined, for cyclically applied stresses, by reference to the hysteresis loop. With regard to the physical meaning of this loop, may it be regarded as the cyclic counterpart of the elastic after-strain before mentioned, or is it a combined effect of permanent set and elastic after-strain? The answer seems to be, in the strict sense, neither; for the cyclical application of stresses, unless very slowly made, leaves very little time for the healing during rest. The internal condition, then, would appear to be very similar to that of the statically overstrained bar immediately after the elastic limit is passed; and when, therefore, no period of rest has differentiated the strain into elastic after-strain and permanent set.

In the ultimate stage of fatigue, the cracks which finally end in rupture are doubtless produced by the continual to and fro sliding along crystalline cleavage surfaces. This action causes the attrition and removal of material from between these surfaces (Ewing and Humphrey, No. 27). It is reasonable to suppose that such to and fro sliding is in operation from the time of appearance of a hysteresis loop; and upon this is based the commonly accepted explanation of plastic hysteresis.

The work of L. Bairstow (No. 4) has thrown much light on plastic hysteresis. When the cycles consist of unequal + and − stresses, he has demonstrated that, before adjustment of elastic limits to a range of stress, the hysteresis loop is not closed; and that plastic hysteresis then consists of a cyclical strain, called by him 'cyclical permanent set,' which is accompanied by an average strain of gradually increasing amount, named (the tensile maximum stress being greater than the compressive) 'permanent extension.' If the range is not too great, the 'permanent extension'

* Rosenhain, *Iron and Steel Inst. Journal*, vol. lxx., 1906.

† The hard and soft states in metals, *Engineering*, May 19, 1911.

‡ *Strength of Materials*, Art. 41.

gradually ceases to increase, and the 'cyclical permanent set' gradually tends to disappear; with such disappearance the elastic limits become adjusted to the stresses, and the material recovers its elasticity. Recovery during cycles of equal ± stress was observed by Bairstow (No. 4), the width of the hysteresis loop being seen to decrease with repetitions of the same stresses. Recovery under equal stress alternations is usually masked in fatigue tests by the circumstance that the primitive elastic limits are further apart than the adjusted limits; but some tests of Rogers (No. 62) of heat-treated steel appear to show adjusted limits higher than those found by static tests on the same treated material.

Recovery during repetitions of stress is difficult to explain. The healing up, which occurs with rest after a single overstrain, is not by itself a sufficient explanation, for the stresses succeed each other too rapidly in alternating stress tests for any material healing up to take place in any one cycle. It has been shown (No. 82) that adjustment of elastic limits (and therefore recovery) occurs not only with slow repetitions of two cycles per minute, but also with 800 cycles per minute; and, of course, the existence of safe ranges of stress, one of whose limits may be outside the primitive elastic limits, is a fact known since the time of Wöhler. It may be conjectured that recovery during cyclical stressing is a slow continuous action due to change in the material between slipping cleavage planes. The slowness of this action, in tests at laboratory or workshop temperatures, still obtains at higher temperatures; but it appears from the experiments of Unwin* (No. 91) and Howard (No. 47) that the resistance to fatigue was somewhat greater at 400° to 500° F. It may be noticed that the energy corresponding to the hysteresis loop, which may cause considerable rise of temperature of the test piece, is generated at the slipping cleavage surfaces, which is the very locality where increased temperature will have its greatest effect.

The small increase of resistance to fatigue mentioned above may possibly result either from a tendency to create a more extended elastic range (due to recovery at the higher temperature, in which case the adjusted elastic limits would be further apart); or merely from a greater healing tendency counteracting the disintegrating action of the to and fro slipping, but not leading to any extension of the elastic range; or from both these two together: the three suggested alternatives being, of course, different aspects of the same thing. The first of the three seems improbable from some experiments of Bairstow (No. 4) on alternate boiling and overstrain of a specimen previously subjected to repetitions of stress in his machine. The considerations concerning temperature and recovery in static tests, also, are in accordance with this view. In short, it seems probable, though not quite certain, that for large limits of temperature the rapidity of (or rather slowness), or degree of tendency to, recovery is somewhat affected, but not the extent of the elastic ranges of iron and steel.

It should be noticed that Howard in a further paper (No. 48) found the resistance to fatigue much increased for tests carried out at 400° to 600° F. Whether the increase of 100° F. between the experiments of Howard's papers No. 47 and No. 48 corresponds to some critical change in tempera-

* Unwin attributes the increased resistance rather 'to the annealing effect each evening when the bars were left to cool.'

ture effect on unstable material between slipping cleavage surfaces, it is impossible, so far as the writer is aware, to say.

A point worthy of notice in Bairstow's experiments (No. 4) is that the increase of width of hysteresis loop for a given increase of range applied was greatest for equal ± stresses. It would be expected that, with the accompanying increase of 'permanent extension' under unequal ± stresses, the increase of width of loop would have been the greater. That it is otherwise indicates that recovery must be in comparatively rapid operation during the increase of 'permanent extension,' so as to effect a continuous (because less interrupted) healing of the average amount of strain per cycle.

In view of Coker's (No. 18) and McCaustland's (No. 55) conclusions concerning absence of recovery at 0° C., experiments such as Bairstow's, conducted at 0° C., should throw light on the operation of recovery, especially in the case of cycles of unequal ± stresses. Hopkinson has already suggested that his own experiments (No. 43) should be carried out at higher temperatures.

Elastic Hysteresis.

When a metal is put through a cycle of stress of which the extreme stresses are less than any known elastic limit or limits of the material, the stress-strain diagram is found to be not a straight line, but a closed curve containing a very small area (No. 26). The name of 'elastic hysteresis' is given to this phenomenon; its physical nature is not understood.* A review of recent papers on the subject is given in Appendix I. of this Report.

In the first place, there is ground for belief that the increased decrement which has been observed after long-continued torsional oscillation of wires, and the subsequent decrease of decrement with rest, are accidental circumstances pertaining to the use of wires in decrement experiments, but otherwise quite extraneous to the phenomenon of elastic hysteresis. The drawing process of wire-manufacture renders material liable to give abnormal results, and it appears probable that these effects are due to crystalline cleavage slipping, of which they are quite characteristic. Hopkinson and Williams (No. 45) found no perceptible increase of hysteresis with a quarter of a million stress-cycles on a steel bar; correspondingly, if no 'fatigue of elasticity' (as this alleged increase of hysteresis has been called) occurs there would be no corresponding recovery of elasticity. Should this absence of fatigue of elasticity be supported by further experiment, alleged points of resemblance between elastic hysteresis, and fatigue of strength and recovery of elasticity in plastic hysteresis, would disappear.

It may be remarked that there is good ground for believing that elastic hysteresis will always accompany plastic hysteresis. The latter is an aggregate effect of movements in the crystals, and is of much greater magnitude than the former; but it seems clear that in general the cleavage slipping of plastic hysteresis affects at the same time only parts of a portion of the whole number of crystalline grains composing a material; thus the remaining parts and grains will doubtless be affected with elastic hysteresis.

The chief contrast between the two kinds of hysteresis is furnished by

* The following articles should be consulted: 'Viscosity of Solids,' Art. 54; Love's *Theory of Elasticity*; Art. 56, Ewing's *Strength of Materials*; Article 'Elasticity,' Lord Kelvin, *Ency. Brit.*, 9th ed., vol. vii.

certain effects of temperature. So far as the writer knows, there are no actual measurements giving a comparison of the actual amounts of hysteresis, of either variety, at various temperatures. But it appears to be certain from experiments on torsional oscillations of wires that increase of temperature causes considerable increase of decrement of oscillations—*i.e.*, increased loss of energy by increased elastic hysteresis. On the other hand, the effect of temperature on plastic hysteresis is complex (see article 'Recovery of Elasticity' in this Report); the tendency is for decrease with higher temperature, owing presumably to increased potency of recovery by 'healing' together of displaced portions of crystals.

These temperature effects are evidence of a difference of nature, and not merely of degree, between the two kinds of hysteresis. The question arises whether elastic hysteresis under cyclically applied stresses causes weakening or predisposition to plastic hysteresis. The suggestion of Bairstow (No. 4) that 'below the static yield-point, iron and steel appear to be capable of maintaining an unstable condition for a considerable time against cyclical variations of stress' admits of a different and more simple explanation (see No. 66). Hopkinson, as already mentioned, found no sign of increase of (elastic) hysteresis with 250,000 repetitions of a range of stress of 28·6 tons per square inch; and the results of experiments on resistance to alternating stress provide many instances of very long-continued cyclic stressing without fracture. Thus, 200 million revolutions in a rotating-bar machine with calculated stresses of ± 40,000 lb. per square inch (No. 48) have been withstood without fracture by a steel specimen.

It is interesting to know that the experiments of Hopkinson and Williams (No. 45) are being continued, with the general object of discovering how elastic hysteresis is related to the elastic limit.

Speed Effect.

The influence of high rate of alternation of stress is to increase the number of repetitions required for fracture, and *apparently* to increase the Wöhler range (No. 43). It is pointed out in No. 43 that the range may not really be increased; but that, on account of the large number of cycles required to fracture a specimen, the practical effect is virtually to increase the endurance either in range or number of cycles.

Speed effect does not appear to become apparent at less than 2,000 reversals per minute. (See Nos. 23, 43, 80, 65, 82, and 84; also No. 59.)

The article on 'Probable Causes of Speed Effect' on p. 147 of No. 43 should be consulted; and reference may be made to the article 'Recovery of Elasticity' in this Report.

*Divergent Results of Fatigue Tests.**

Suggested Causes.—(1) Impurities (No. 3), flaws, &c. (No. 94), incipient cracks (No. 23) (such as would be left by a lathe cutting tool after a deep cut). The improved endurance of ground specimens and of specimens filed and polished, in alternate bending tests, is probably due to the removal of small surface cracks. J. B. Kommers (No. 51) states that polished and also ground specimens showed an increased resistance over turned specimens of 45 to 50 per cent.

(2) Unrecognised stresses, due to bending in a direct stress; to vibra-

* See Note by Mr. E. M. Eden (p. 41).

tion in any kind of test; or to stress accumulation (No. 58). From the known difficulty of getting an axial pull or push in a direct static test, it is to be expected that there will be some bending in alternate stress tests with directly applied tension and compression. In No. 43 it would appear that bending oscillations would surely have been detected by the apparatus used to measure the lengthwise strain. The records of the only other experiments in which strains corresponding to directly applied stresses were measured, viz. Nos. 4 and 74, do not state that any bending effect was observed. It is noteworthy that the experiments in No. 82 with varying ratios between the maximum tensile and maximum compressive stresses gave little variation in the values of the limiting range; showing that bending, if any, had little effect; or that the bending was caused equally during tension and compression. Though it is difficult to draw conclusions, it seems likely that the line of resultant force in the specimen does not appreciably alter its position after the first few alternations of the approximate limiting stresses. This early change of position in this line would be one tending to equalise the distribution of stress in the specimen.*

Alternate bending tests upon solid rotating bars give an apparently greater value for the Wöhler limiting range. The number of revolutions required for fracture is considerably greater than the number of reversals in tests with stresses directly applied. The 'f, n' curves for the former are not, generally speaking, even approximately parallel to the axis of 'n' after 10^6 revolutions; while in the latter there is indication that the curve is asymptotic to a line, parallel to the axis 'n,' and not far removed from the curve, at this number of cycles. It is to be expected that the calculated maximum stresses in a bending test will be somewhat higher than the actual, even when the bendings give the Wöhler limiting stresses, because of stress equalisation near the 'skin' of a specimen (see remarks on No. 23). Unwin remarks † that 'Bending experiments are not less trustworthy than tension experiments, and for stresses considerably less than the statical breaking weight probably the error in the calculated stress is not a large one.' Hollow test bars are found to give 'f, n' curves more nearly approaching the curves for directly applied tension and compression.

Carbon-Content of Steels and Resistance to Alternating Stress.

Speaking of steels which consist partly of pearlite and partly of ferrite, Rosenhain (No. 66) remarks: 'From the point of view of the resistance to comparatively steadily applied alternating stresses, the higher the carbon-content up to 0·9 per cent. of carbon, the better the resisting power of the metal.' Nos. 23, 47, 62, 82, 90, 93, and especially No. 48, contain evidence in accordance with this statement. Heat treatment of steels may have, of course, an enormous influence on their resistance.

Effects of Annealing and Quenching upon Resistance to Alternating Stress.

The effect of the 'annealing' which has been done ‡ upon the specimens of published alternate stress tests has been, in general, to diminish the resistance as compared with that of the material in untreated commercial condition; and the effect of the quenching done has been to

* See No. 82, and *Proc. I.C.E.*, clxvi. p. 100.
† *The Testing of Materials of Construction*, 1910 ed., p. 377.
‡ See Appendix II.

increase the resistance greatly. It is pointed out elsewhere in the Report (Note on 'Heat-Treatment') by Dr. F. Rogers that for adequate study of this branch of the subject very precise information concerning manufacture and of treatment previous to the specific treatment given must be available.

Tests with Repeated Cycles of Combined Stresses.

The question has been raised, notably by Turner (No. 90), whether a common factor may not be found for all kinds of stress systems when these systems are applied in simple harmonically varying cycles. Since the Wöhler limiting ranges have been shown to coincide with the elastic ranges (at any rate for direct stresses) this question becomes very pertinent.

The main result of Turner's experiments is very briefly indicated in the comments on No. 90 in the bibliography. More experimental data are required. The Table (Appendix II.) gives all the information available at present.

Alternate Stress with Repeated Impact.

The very important conclusion (see No. 83) arrived at by Stanton and Bairstow seems to be well substantiated by Roos (No. 64). The practical importance of the discovery may be gauged from the following quotation from No. 83: 'The authors are of opinion that conclusive evidence has been shown that materials which are strong under alternating stresses are in general strong under those shocks which are likely to be put upon them in ordinary machine practice.'

Practical Utility of the Alternate Stress Test.

The practical bearing of Wöhler's results has long been recognised, witness the Launhardt and Weyrauch formulæ. ('Proc. I.C.E.' lxiii. 1880–1. See also No. 3.) In view of the result of No. 83, it would appear that the repeated stress test ought to have enhanced importance. A Wöhler test is rarely specified by engineers, who rely on the general result of research tests and on the convenient 'factor of safety.' Resistance to sudden large shock is of at least equal importance with resistance to alternate stress, and these in general seem to be somewhat opposing requirements. (See Nos. 3, 83, and 66.) The former necessitates ductility, while the latter requires a high natural elastic limit. These exacting and in many cases apparently inconsistent conditions would appear to render the Wöhler test, as well as a sudden large impact test (for the former does not detect brittleness), all the more necessary. But it is unlikely, however, that any test for resistance to repeated stress will be extensively used until a rapid, simple, and inexpensive test has been discovered.

Rapid Means of determining Endurance under Stress Repetition.

(1) Prof. J. H. Smith's Method. (No. 74.)

The method seems to be open to certain objection, and confirmation is required of its validity (see Notes on No. 74 in the bibliography); but there is promise that it may meet the need for a quick method of finding commercially the safe limits for alternating stress.

(2) Professor J. O. Arnold's Test. (Nos. 1, 2, and 3.)

This test does not profess to give the elastic ranges, but only to be a practical substitute for the difficult Wöhler test. The test, however, is

qualitative only; it certainly detects brittleness, which the Wöhler test does not; but whether it can give a quality factor which, besides excluding brittleness, includes resistance to repeated stresses of very small overstrain, is a matter quite unproved.

(3) Method suggested by Bauschinger and latterly investigated by Bairstow (No. 2), viz., a very few repetitions of alternate overstrain and heating to 100° C. This has not been advanced as a quick method for finding the elastic ranges; indeed, further experiment is required. If the method should prove satisfactory for certain classes of steel only, it would seem to be worth while to design special apparatus for carrying out expeditiously the present rather cumbersome process.

Should (1) or (3) be adopted means would have to be taken to discover impurities and flaws, since these, which vastly limit the endurance, would not be detected.

Materials other than Wrought Iron and Steel.

The information concerning the resistance of materials other than wrought iron and steel is not extensive; what the writer has found may be consulted by the aid of the following references:—

Cast Iron.

Endurance tests . .	No. 23.	Alternate + and − bending.
	No. 59.	Alternate direct stress.
	No. 93.	Repeated bending in one direction (see Unwin's 'Testing of Materials').
Elasticity and strains under repeated loading, &c.	Nos. 8 and 9.	

Copper.

Endurance tests . .	No. 23. No. 93.	Alternate + and − bending.
	No. 24.	Alternate combined stress (with considerable overstrain).

Suggestions for Research.

The writer understands that the following researches are in progress:—

High-speed tests on resistance at temperatures of 100° C. and other temperatures.

Experiments on elastic hysteresis on a high-speed direct-stress machine.

Experiments on alternating combined stress.

Experiments on the effect on resistance of keyways, &c.

The following suggestions for further research seem worthy of consideration:—

(1) That experiments be made at 0° C. with unequal ± stresses, in order to study the effect of recovery and adjustment of the elastic limits at that temperature.

(2) That (as suggested by L. Bairstow, No. 2) experiments be made to determine the 'permanent extension,' if any, when the range of stress (direct) is less than the safe range.

(3) That the validity of the method of finding the safe elastic ranges by

two or three repetitions of alternate small overstrain and boiling be further tested.

(4) That the effect of cold working upon the 'natural' elastic limits be further investigated.

(5) It would appear that two desiderata, viz., resistance to repeated stress and resistance to large impact, require somewhat inconsistent qualities in the case of steel. (Nos. 83, 3, and 66.) Thus further work (though probably mainly metallurgical and micrographic) should be done in order to ascertain, if possible, the best conditions for maximum resistance when both kinds of straining action above mentioned operate, as in certain service conditions. A point to be tested is the resistance to sudden impact of steel which has undergone test by alternating stress of approximately the Wöhler safe range.

(6) That an elaborate series of alternating stress endurance tests, all with the same material, be made on all the alternating stress testing machines in use; at the very least twenty test pieces to be tested in each machine, and special precautions to be taken to ensure uniformity in the material.*

Note on Heat Treatment. By Dr. F. Rogers.

The effects of heat treatment upon the resistance of metals to alternating stress form an almost entirely metallurgical aspect of the subject.

The value of some published work is very doubtful, because of the vague use of such terms as 'annealing' and 'quenching.' In order that a heat treatment may be sufficiently specified the following particulars or others from which they may be derived should be given:—

Composition of the steel, process of manufacture, its condition before the treatment in question (whether as rolled or forged, or heat-treated and how), the size of the piece, top temperature of the treatment, duration of heating at that temperature, rate and manner of cooling, whether in a furnace, in the air, or a liquid.

A so-called annealing of a small piece may happen to be equivalent to the quenching of a large piece at some point in the large piece, except in so far as the result is affected by the previous treatment in each case.

The present state of knowledge is such that the condition of the material can frequently be equally well, if not better, defined by the results of various familiar mechanical tests, together with composition and microstructure, as by a precise statement of the known portions of the heat treatment. On this account, when the effects of heat treatment on the endurance under alternating stress are being dealt with, it is desirable that as much collateral information about the material as possible should also be given. Largely on account of the more or less natural jealousy of manufacturers, little information of practical value has been published.

It may be as well to confine present attention to carbon steels of carbon contents not exceeding what is usual in rails, say about 0·50 per cent. carbon, since practically no information on the remaining steels is to be found in the literature.

The complexity of the subject has already been suggested. Further, however, it is necessary to remember that in any dynamic tests the relative

* Suggested by Mr. E. M. Eden.

importance of a flaw such as a crack, a non-metallic enclosure, or even a tool-mark, is relatively very great, and depends upon the composition generally, increasing, for example, with the carbon content. Heat treatment may increase or decrease the relative importance of such flaws according to the kind of treatment and the previous condition of the steel.

Apart from flaws of the kinds mentioned, steel in the rolled or forged condition occasionally happens to be weak dynamically. For the present purpose it appears necessary to consider the effects of heat treatments upon steels in the rolled or forged condition which are not weak from either of these causes.

There are then three main classes of treatments to consider:—

(1) *Overheating.*—This in general diminishes the endurance under alternating stress (62 and 87). When extreme it merges into 'burning,' from which it is distinguished technically. Slight overheating, on the other hand, is the same thing as some of the processes which are called annealing.

(2) *Reheating through the critical range* is, in general, capable *per se* of bringing the endurance to a normal high value, or of leaving it undisturbed, according to the state of the steel before the treatment (Nos. 62, 85, 86, and 87). The following factors tend to make the effects of such reheating approximate more and more to those of overheating: (*a*) the more the temperature exceeds the upper limit of the critical range; (*b*) the greater the duration of heating above the lower limit of the critical range; (*c*) the slower the cooling through the critical range (62).

(3) *The speed of cooling through the critical range* has in any event a most profound influence upon the endurance under alternating stress. Generally speaking, it appears that the more rapid this cooling the greater is this endurance (62, 33).

As to the effect of *Cold Work* upon endurance of alternating stress, there are no data available. It is well known to manufacturers that it increases the endurance greatly in some cases—for example, wire. This fact also explains partly why in some published experiments (*e.g.*, 62) 'annealing' diminished the endurance. The bars from which the tests were cut were of small section, and therefore they were somewhat cold worked, and also relatively rapidly cooled, in manufacture. They were much more slowly cooled in some of the experimental annealings.

The effect of annealing after a metal has withstood large numbers of alternations is also one which can only be answered when many practical particulars of the metal are known. In (47) no effect was found. In (62) it was clearly proved why no effects could be obtained from annealing after a certain stage of the fatigue had been passed. At a comparatively early stage minute incipient cracks are sufficiently open to contain air. Hence the faces oxidise, effectually ending any possibility of reunion.

Note on Microscopic Effects of Alternating Stress.
By Dr. F. Rogers.

This has been exhaustively elaborated in a very few papers. The main conclusion is to show that cracks form by the development of repeated cleavage, seen as slip-bands. This was done in (27) for iron, and in (62, 63, and 82) for steel. In (63) and (82) the influence of the constituents is noted, and in particular the avoidance of the harder carbon containing

constituent by the incipient fracture is noted.* Further, the fatigue of steels which had been variously heat-treated on systematic lines is similarly studied. This helps to throw light upon the overheating of steel &c.

Remarks on the Phrase 'Crystallisation through Fatigue.'

From views which I have elsewhere expressed (No. 63A) as to the microscopic nature of strain effects it will doubtless be expected that I do not endorse the use of this hackneyed phrase. Twinning and the recrystallisation of polyhedric steels might, however, be regarded as admissions of the possibility of recrystallisation after straining, and therefore possibly after fatigue. But my view is that the expression arose through the crystalline appearance which is well known upon the fracture of defective iron, and was later sometimes found on fractures of relatively brittle steel. I always find evidence that when such 'crystalline' fractures are obtained they can also be obtained without fatigue; and, further, that metal which gives a fibrous or silky fracture does not develop 'crystalline' fractures by fatigue.

Note on Stress Alternation Curves for Bending Tests on Rotating Bars. By E. M. Eden.

Wöhler's rotating cantilever experiment showed that n (the number of rotations to fracture) depended on f (the maximum stress). For two materials 'Phœnix Iron' and 'Homogeneous Iron' a fairly definite curve can be obtained by plotting the stress f against the number of alternations n, the curve extending in the case of the Phœnix Iron from $n = 50{,}000$ to $n = 20{,}000{,}000$, and in the case of the Homogeneous Iron from $n = 3{,}000$ to $n = 4{,}000{,}000$.

The other materials experimented with by Wöhler appeared to obey similar laws, but the results were much more irregular.

Later rotating beam experiments than Wöhler's on steel, iron, and copper confirm the form of f, n curve given by these wrought-iron tests, but the more modern experiments have usually only carried the f, n curve up to $n = 10^6$. The form of the f, n curve suggests that there is a limiting value of the stress f below which fracture cannot be caused by any number of alternations; this limiting stress may be called f_l. Values have been assigned to this limiting stress by Wöhler, but I cannot see any reason for thinking that the values he gives are correct.

In practice, material does not have to withstand an indefinite number of alternations of stress, but the useful life of some machinery may involve some hundreds of millions of alternations of stress. In solid rotating beam tests the resistance of a material to 10^8 alternations (f_{10^8}) would appear to be considerably lower than the resistance to 10^6 alternations (f_{10^6}).

f_l, the limiting stress, is the value of f where the f, n curve is horizontal; as far as I know it has not been reached in any solid rotating beam test.

Alternating stress tests in direct tension and compression on reciprocating weight-testing machines with a presumably uniform distribution of stress over the cross-section of the test piece show f, n curves, which although in many cases rather vague in form are more nearly hori-

* For a review of this question see 78.

zontal after 10^6 alternations than the curves from solid rotating beam tests, and it is possible that in these tests the limiting stress f_t has been nearly reached or that f_{10^8} may not be much lower than f_{10^6}. Quite lately it has been shown that rotating cantilever tests with hollow test pieces where the stress should be nearly uniform over the cross-section also give a curve more nearly horizontal at 10^6 alternations than the curve from solid test pieces;* in fact, f_t appears to have been reached with 500,000 alternations.

These hollow cantilever tests help to explain the difference between the form of f, n curve obtained from the rotating bar and reciprocating mass types of testing machine, but unfortunately this is not the only difference in the results of tests on the two machines.

Note on Divergent Results of Alternating Stress Tests.
By E. M. EDEN.

In the reciprocating weight-testing machine, rate of alternation of stress, number of revolutions per minute, largely affect the endurance strength, whereas in a rotating-beam machine the endurance strength is quite unaffected by speed.

Although, as far as I know, alternating stress tests of the same material in different testing machines have not been published, yet it appears to be impossible for the two types of machine just mentioned to give the same endurance figures, as if they did agree at one speed they would not do so at another. It appears that endurance under an alternating stress or resistance to an alternating stress cannot at present be determined for any material—the values obtained will depend on the testing machine that is used.

In the Reynolds-Smith endurance tests with a reciprocating weight machine a high tenacity steel showed a lower endurance strength than a steel of much lower tenacity. Such a result has never been obtained with a rotating-beam machine where increase in endurance usually accompanies increase in tenacity, and this again rather points to some unexplained difference in the destructive action of the two types of machine.

Apparently either the calculated stress in one or both types of testing machine is not the true stress, or something else besides the intensity of the alternating stress affects the endurance.

In either case the *calculated* values of f_t and f_c are not the only factors affecting the endurance of a piece of material.

There are some other factors besides f_t and f_c which are known to affect endurance; the distribution of the stress over the cross-section has been referred to before, and the condition of the surface, and the form of the test-piece, are also known to largely affect endurance, but none of these can explain the speed effect.

In this connection it is, I think, worth noticing that it is not at all easy to repeat an endurance test and obtain exactly the same result. Two test pieces cut from the same bar of metal will not usually show the same endurance when tested under what are intended to be the same conditions, on the same alternating stress-testing machine; a great deal depends on the machine and on the care taken; but in many published tests there is a great want of agreement between different tests of what is said to be the

* 'Welded Joints in Iron and Steel.' *Proc. I.C.E.*, vol. clxxxviii.

same material, and it is probable that many unpublished tests would show even larger variations.

This variation in the apparent endurance strength of test pieces cut from the same bar may be due to an actual variation in the material, to local weak spots in the structure of the bar, or to differences in the amount of surface damage in machining or grinding the test pieces, or they may be due to the test piece really being treated differently in testing, such as one piece being run more out of truth than another.

While there is no doubt that in the case of some materials there may really be a difference in different parts of the same bar, yet there is some evidence that the apparent variation in endurance strength is not always due to this alone. In the alternating shock or Repeated Impact Tests of Dr. Stanton * different test pieces from the same bar of steel gave practically identical endurance results. If the variation in endurance of different test pieces from the same bar when tested in an alternating stress-testing machine is due to variation in the material, it is remarkable that alternating shock tests should not be affected in the same way, for the impact tests referred to are really alternating stress tests with suddenly applied stresses, which are not calculated in tons per square inch.

Alternating stress in practice is often accompanied with repeated shocks or occasional shocks or vibrations. In a testing machine such shocks or vibrations are as far as possible eliminated, but it may be that these or the stresses caused by these affect the endurance.

Suggestions for Experimental Work.—There seems to be room for a great deal of purely experimental work on alternating stress and endurance; to help to clear up some of the immediate difficulties of the subject I would suggest:—

(1) An elaborate series of alternating stress endurance tests all with the same material on all the alternating stress-testing machines in use, at the very least twenty test pieces to be tested in each machine, and special precautions to be taken to ensure uniformity in the material.

APPENDIX I.

Brief Review of the Papers in the Bibliography on Internal Friction, Hysteresis, Effects of Magnetism, Temperature, and Oscillatory Discharge. By Dr. F. Rogers.

The estimate (in 45) of the area of the hysteresis loop in 'static' tests, as being, say, 10 to 20 per cent. greater than in alternating tests at a speed of average frequency of 136 alternations per second, is of much interest, and it would be of value if direct confirmation could be otherwise obtained.

It is of great importance to inquire whether this hysteresis at stress well below the elastic limit, determined statically by a good extensometer, is (*a*) simply a matter of local permanent set beyond the elastic limit owing to microscopically visible or other want of homogeneity; or (*b*) strain of some sort which is as homogeneously distributed as purely elastic strain is commonly supposed to be, and therefore possibly dependent upon intermolecular distances, or even upon orientations of molecules or of relatively small groups of molecules. Since magnetisation of a bar is accompanied by a change of length, and since straining of a bar assists the bar to take

* *Proc. Inst. Mech. Engs.*, No. 4, 1908.

permanent magnetisation, it is conceivable that the mechanism involved, whatever precisely it may be, is the same for both mechanical and magnetic hysteresis ; or (*c*) a combination of these two.

Most frequently this aspect of the subject has been studied by observation of the torsional oscillations of wires. The decrement of oscillations appears to be increased by :

Temperature above atmospheric (36, 38, 37).

Temperatures below $-80°$ C. for gold and magnesium (38), or -40 for gold (36).

Very high frequency oscillatory discharge (20).

It is decreased by :

Temperatures below atmospheric.

In No. 36 this decrease is found for copper, platinum, silver, and steel ; gold having a minimum at $-40°$ C.

In No. 37 this decrease is found for silver, iron, and more especially aluminium ; magnesium and gold having a minimum at $-80°$ C.

(Exceptions are noted above.)

Magnetic field, particularly alternating (34, 19, 20).

Oscillatory discharge (34, 19, 20).

(34 is concerned with *tensile* hysteresis.)

On the other hand (12), successive torsions decrease the magnetisation in a given field.

A relation between the decrement and the maximum strain is not in most cases available, but would be desirable from the point of view of answering the above inquiries. A glance at this summary suggests, however, that the analogy between mechanical and magnetic hysteresis (*b*) finds some support. An important limitation is, however, suggested by the fact that whereas an alternating magnetic field tends to diminish the energy absorbed in mechanically straining (19, 20), yet, on the other hand, repeated torsion causes an increase in the energy required for magnetisation (12).

The suggestion should be regarded rather as a basis for investigation, than as based upon existing data.

Bibliography on Alternating Stress.

Drawn up by W. Mason *and* Dr. F. Rogers.

1 Arnold, J. O. 1903 Dangerous Crystallisation of Mild Steel and Wrought Iron. (Description of Main Features of Arnold's Alternate Bending Machine.) 'Inst. C.E. Proc.,' 154. Supplement, 1903.

2 Arnold, J. O. 1904 Fracture of Structural Steels under Alternating Stress. 'Brit. Assoc. Report,' 1904. 'Science Abs.,' 1904, Nos. 1929B, 2795B.

Some preliminary experiments indicated that the resistance of structural steel to cycles of stress with considerable overstrain was inversely as the rate of alternation.

3 Arnold, J. O. 1908 Factors of Safety in Marine Engineering. 'Inst. Naval Arch.,' L., 1908.

An analysis of 'factors of safety' for various purposes is given ; and the practical importance of the Wöhler phenomenon shown.

The author demonstrates that the Wöhler test does not detect brittleness—a fact now accepted. He argues that the Wöhler limiting stresses

APPENDIX II.

Available Data on the Effect of Annealing on Endurance and on the Comparative Endurance in ± Direct Stress (or Bending) and ± Torsion.

Experimenter	Material	Condition of Material	Static Test Stresses		Wöhler Range in Endurance Tests		
			Tensile E. Limit	Torsion E. Limit	± Direct Stress	± Bending	± Torsion
			tons sq. ins.		tons sq. ins.	tons sq. ins.	
Rogers, F.	0·14% C. Steel	As rolled	16·16	—	—	±16·0 (about)	—
	,, ,,	Annealed ½ hour at 670° C.	14·9	—	—	±16·0 (about)	—
	,, ,,	Annealed ½ hour at 1010° C.	10·82	—	—	±16·0 (about)	—
,,	0·27% C. ,,	As rolled	24·4	—	—	±19·0 (about)	—
	,, ,,	Annealed ½ hour at 655° C. and slowly cooled	—	—	—	±17·5 (about)	—
	,, ,,	Annealed 3 hours at 1215° C.	11·76	—	—	—	—
,,	0·32% C. ,,	As rolled	16·7	—	—	±14·0 (about)	—
	,, ,,	Annealed ½ hour at 675° C	12·5	—	—	±14·0 (about)	—
	,, ,,	Annealed ½ hour at 1150° C.	7·1	—	—	±13·0 (about)	—
	,, ,,	Annealed 2 hours at 1150° C.	7 5	—	—	±13·0 (about)	—
Ross, J. O.	0·11% C. ,,	Annealed ½ hour at 850°, cooled in air	23·2	—	—	±16·0	—
,,	0·40% C. ,,	,, ,,	35·7	—	—	±22·0	—
,,	0·65% C. ,,	,, ,,	35 8	—	—	±25·0	—
Smith, J. H.	0·19% C. ,,	As rolled	—	—	±11·7	—	—
	,, ,,	Annealed at 900° C.	—	—	±11·0	—	—
,,	0·24% C. ,,	As rolled	—	—	±14 0	—	—
	,, ,,	Annealed at 950° C.	—	—	±12·2	—	—
,,	Nickel Steel, 3·56% Ni.	As rolled	—	—	±17·2	—	—
		Annealed at 750° C.	—	—	±16 8	—	—
			lb. sq. in.	lb. sq. in.		lb. sq. in.	lb. sq. in.
Turner, L. B.	Tube Steel	As rolled	50,000	29,500	—	±33,000	±16,000
,,	,,	Annealed 3 mins. at 760°, cooled in sheath	31,000	17,000	—	±29,000	±16,000
,,	Mild Steel from Crank Shaft	As rolled	—	—	—	—	—
		Annealed at 760°	42,300	24,000	—	±40,000	±22,000
,,	Tool Steel	As rolled					
	,,	Annealed 4 mins. at 760°, cooled in air	67,000	38,400	—	±50,000	±38,000
,,	Nickel Steel	As rolled	—	—	—	±62,000	±37,500
	,,	Annealed 12 mins. at 800° C., cooled in air	81,200	40,800	—	±59,000	±35,000
Wöhler (See Unwin's Testing of Materials)	Krüpp Cast Steel Axle	—	—	—	lb. sq in. From 0 to 52,000	From 0 to 61,000	From 0 to 41,000
			—	—	—	±33,500	±27,000

Note.—In some experiments preliminary to those of No. 82, Stanton and Bairstow found that by heating specimens to 1,000° C. and allowing them to cool slowly in air, their resistance to reversals of stress was reduced by 15 to 25 per cent. Reynolds and Smith (No. 59) also found a reduction in resistance. See also Nos. 85, 86, 87 in bibliography.

(equal ± alternations of stress) are a 'reflection' of the yield point or elastic limit, giving figures in support—a contention not borne out by nearly all other tests.

The effect upon resistance to fatigue of microscopic 'rods' of manganese sulphide is shown; tests being made with stresses parallel and also perpendicular to the length of the 'rods.'

4 Bairstow, L. 1909 Elastic Limits of Iron and Steel under Cyclical Variations of Stress. 'Phil. Trans. Roy. Soc.,' 210, Dec. 9, 1909.

This paper is a very important contribution to the subject of alternating stress. The author has thrown much light on the strain history of the Wöhler test on iron and steel, and has revealed the nature of the stress-strain relations, whether of hysteresis or permanent extension, throughout his tests. The main conclusions are mentioned in various places in the Report, and only one or two salient facts need be mentioned here. He has proved the existence of elastic ranges of stress which were suggested by Bauschinger as the explanation of Wöhler's results; and from comparison of these elastic ranges (ranges for which the hysteresis loop disappears), with the safe limiting ranges found by Wöhler for presumably similar material, he has concluded that the former are identical with the latter.

Work (previous to Bairstow's) on the points just mentioned is contained in No. 7, Bauschinger; No. 82, Stanton and Bairstow. See also Unwin's 'Testing of Materials,' Article 253, edition 1910.

5 Baker, E. 1905 Report of Tests of Metals. Abstract in 'Iron and Steel Inst. Journ.,' 1905, II., p. 768.

Tests of material at the Watertown Arsenal. Re-tests made of wrought iron, following a period of rest of twenty-two years, showing that certain tensile properties characteristic of the early overstraining still remain in the iron.

6 Baker, Sir E. 1886 Influence on Steel of repeated subjection to Stress. 'Proc. Inst. Civil Engineers,' cxxiii. See Unwin's 'Testing of Materials.'

7 Bauschinger, J. 1886 Ueber die Veränderung der Elasticitätsgrenze und Festigkeit des Eisen, etc. 'Mitthlg. aus dem Mechanischtechnischen Laboratorium in München.' See Unwin's 'Testing of Materials,' also for Bauschinger's earlier paper.

8 Berger, Karl 1899 Elasticity of Cast Iron subjected to repeated tensile and Compressive Strain. See Abstract in 'Proc. Inst. Civil Engs.,' cxxxvi. 370.

No particular value can be assigned for the elastic strain due to a definite load, since this strain depends upon previous loadings. See No. 9.

9 Berliner, S. 1906 Behaviour of Cast Iron under slowly Alternating Stress. 'Ann. de Physique,' 20, 3, June 1906. 'Sc. Abs.,' 1906, No. 1528.

Investigation of the amount of strain after successive loadings of cast iron in equal tension and compression $\pm p'$. An expression is given for the strain at any stress p, after such loadings, in terms of p and p'. Similar work for ± torsion of cast iron. See No. 8.

10 Blount, B.; Kirkaldy, W. G.; Sankey, H. R. 1910 Tensile, Impact Tensile, and Repeated Bending Tests of Steel. 'Inst. Mech. Engs. Proc.,' 2, 1910. 'Sci. Abs.,' A, 300, 1911.

In the repeated stress tests the specimen is bent to and fro in a machine worked by hand. The angle of bending on either side is 46½°, and a very few cycles break the specimen. The work done is automatically recorded and is found to be a measure of the ductility. See No. 3.

11 Bouasse, H., and Carrière, L. 1908 Decay of Oscillations. 'Sci. Abs.,' 1908, No. 1225. 'Annal. Chem. Phys.,' 14, June 1908, also 'Annal. Chem. Phys.,' 2, May 1904.

See Report, Appendix I.

12 Bouasse, H., and Berthier | 1907 | Decay of Oscillations. 'Annal. Chem. Phys.,' 10, Feb. 1907. 'Sci. Abs.,' A, 1907, No. 710.

See Report, Appendix I.

13 Bondouard, O. | 1910 | Tests on Metals by study of the damping of Oscillations. 'Comptes Rendus,' 150, Mar. 14, 1910. 'Sci. Abs.,' 1910, No. 645.

14 Bondouard, O. | 1910 | Tests of Metals by the Abatement of Vibrating Movements. 'Comptes Rendus,' 152, Jan. 3, 1911. 'Sci. Abs.,' 1911, No. 295.

15 Bondouard, O. | 1912 | Breakdown Tests of Metals. (Alternate Bending.) 'Intern. Assoc. for Testing Materials,' Paper V. 3, 1912.

The tests of Nos. 13, 14, and 15 were made on bars 1 cm. $\times \frac{1}{2}$ cm. $\times$ 20 cm. to 30 cm. long; these were clamped in a vice, and vibrations of the free end started and maintained by an electro-magnetic device. The free end of the bar carried a mirror, from which photographic records were obtained of the oscillations.

Tests were made, under continued oscillation, of commercial steels of 0·3 per cent. carbon and other steels, the tests being made on this material as received, after annealing, and after tempering. The resistance to fatigue was found to be in the order just mentioned, the tempered specimens having the lowest resistance. It is stated that the numbers of vibrations before fracture are inversely proportional to the carbon content; puddled iron being more resistant than soft Martin's steel. Under the test, 0·3 carbon steels showed no sensible difference between the 'annealed' and hardened states; but with high carbon steels, hardening considerably diminished the time for fracture at a given rate of oscillation.

These results are directly opposed to those of Nos. 23, 93, 62, 90, 47.

It is stated that the stresses were below the 'elastic limit,' but no calculation is given of the stresses. The numbers of oscillations before fracture were, however, between one and two millions in certain cases.

16 Breuss, E. | About 1905 | History of Fatigue Tests of Metals. 'Baumaterialenkunde,' xi., pp. 245–249.

17 Coker, E. G. | 1898 | Endurance of Steel Bars subjected to Repetitions of Tensional Stress. 'Proc. Inst. Civil Engineers,' cxxxv. 294.

Shows that very large elongation may be produced by repetitions of a process of alternate stressing beyond the yield point and annealing.

18 Coker, E. G. | 1902 | Effect of Low Temperature on Over-strained Iron and Steel. 'Phys. Rev.,' 15, Aug. 1902. 'Sci. Abs.,' 1903, No. 227. See also E. J. McCaustland, No. 55.

A temperature of 0° C. appears to prevent recovery from tensile overstrain; and moreover to retard recovery when the temperature is afterwards made normal.

Recovery appears to proceed more slowly in the case of steels with larger percentage of carbon.

19 Drago, E. | 1911 | Influence of Oscillatory Discharge on Decay of Torsional Oscillations. 'Accad. Lincei,' Atti 20, pp. 100–107. 'Sci. Abs.,' A, 1911, 1423.

20 Drago, E. | 1911 | Influence of Oscillatory Discharge on Decay of Torsional Oscillations. 'Accad. Lincei,' Atti 20, pp. 369–376. 'Sci. Abs.,' A, 1912, 2.

For Nos. 19 and 20, see Report, Appendix I.

21 Dudley, C. B. | 1904 | Alternate Bending Stresses. 'Iron and Steel Metallurgist,' Feb. 1904.

A photograph shows fatigue fractures of an axle, a bolt, and three rotating bar test pieces. The conclusion is drawn that if one is having trouble with 'detail' (*i.e.*, fatigue) fractures the best cure is to adopt a stiffer, *i.e.*, harder, steel.

Three examples are given which illustrate the conclusion. These are (1) On the Pennsylvania Railroad, many fatigue failures of axles were obtained with acid open-hearth axles containing 0·25 to 0·28 per cent. carbon, with a tensile strength of 29 tons per square inch, and 25 per cent. elongation. The maximum calculated stress in the middle of the axle was 6·8 tons, and in the journal 3 tons, per square inch. These axles failed in the journal. Steel of about 36 tons tensile was then substituted, and this cured the trouble.

(2) 0·22 to 0·25 per cent. carbon steel rollers for a sugar mill used to break, and these were successfully replaced by rollers of 0·40 to 0·45 per cent. carbon steel.

(3) A soft tough steel was successfully replaced by a higher carbon steel for use in the form of piston rods for steam hammers.

On the above subject there is, and perhaps always will be, much divergence of opinion. The chief reason is that conditions vary so greatly. The treatment of the steel is obviously a very important factor. The axles, for example, if treated at all, could have been treated so as to give different, and probably much better, results, and to some users this would have formed a more acceptable solution of the problem. One has to allow, amongst other things, for considerable shock and some ill-treatment. This is emphasised by the fact that the calculated stress in the journals is only 3 tons per square inch. No Wohler test results are given.

22 Eden, E. M. 1910 Endurance of Metal under Alternating Stress and Effect of Rate of Alternation on Endurance. 'Univ. of Durham Phil. Soc. Proc.,' 3, 5, 1910. 'Sci. Abs.,' 1910, No. 1384.

23 Eden, E. M., Rose, W. N., Cunningham, F. L. 1911 The Endurance of Metals. 'Proc. Inst. Mech. Eng.,' 4, Oct., Dec. 1911. 'Sci. Abs.,' 1912, No. 1145.

The main results of these well-known experiments were :—

No 'speed effect' between 250 and 1,300 r.p.m.; agreeing with Nos. 43, 80, 65 and 82.

Greater resistance of high tenacity steels; agreeing with Nos. 93, 82, 62, 90, 47 and 48.

Tests with loaded rotating solid bars appear to give either a higher limiting range of stress (calculated by the usual theory of bending) or require a larger number of cycles to fracture than direct-stress experiments; a result in agreement with Nos. 47, 48 and 93. The tests of these papers (Nos. 22 and 23) were carried to fracture or to 10^6 revolutions. In No. 43 a small difference only was found in some comparative tests on machines of the rotating bar and reciprocating mass type.

Rest intervals during a test appear to have little effect. This appears to be the case in all tests with cycles of equal ± stresses.

The effects of the kind of finishing process used in preparing the specimen, and of the kind of finished surface, are found to be important. See also No. 51.

A few cast-iron and copper specimens were tested. The relative resistance of certain forms of specimens was tested, with results in agreement with Nos. 74, 75, 82 and 93.

24 Ercolini, G. 1906 Effect of Deformation upon Torsional Couple exerted by a Twisted Wire. 'Accad. Lincei,' Atti 15, Sept. 2, 1906. 'Sci. Abs.,' 1906, No. 1807.

Some experiments with combined stress and with alternating combined stress on copper wire. The strains appear to have been considerably beyond the elastic limits.

25 Ercolini, G. 1909 Recent Experiments on Elasticity. 'Sci. Abs.,' 1909, No. 965.

The following is quoted from 'Science Abstracts': 'It is concluded that the damping of vibrations is due to the dissipation of energy corre-

sponding to the hysteresis effect on taking a specimen through a cycle of strain, and not to molecular friction.' The meaning of this is not clear.

26 Ewing, Sir J. A. 1889 On Hysteresis in the Relation of Strain to Stress. 'British Assoc. Report,' 1889. See also Ewing's 'Strength of Materials.'

27 Ewing, Sir J. A. and Humfrey, J. C. W. 1902 Fracture of Metals under Alternations of Stress. 'Phil. Trans.,' A, 200.

The important conclusions are well known, and therefore do not require to be quoted. For further micrographic work, see Nos. 62, 63 and 82.

28 Fairbairn, Sir W. 1864 The Effect of Impact Vibratory Action and Changes of Load on Wrought-iron Girders. 'Phil. Trans. Roy. Soc.' See Unwin's 'Testing of Materials.'

29 Finley, W. H. 1906 Case of Failure of Iron from Fatigue. 'Engineering News,' 55, p. 487. 'Sci. Abs.,' A, 1906, 1200.

Coupling pin of a 'mine trip' found to be brittle. Toughness was restored by 'annealing.'

30 Foster, F. 1903 Repetition of Stress. 'Mech. Eng.,' Nov. 22, 1902. 'Sci. Abs.,' 1903, No. 866.

It is suggested that fatigue is an effect of accumulated permanent strain, the latter being the aggregate of a prolonged series of hysteresis loops. The relation between permanent extension and hysteresis is cleared up in No. 4.

31 Frémont, C. 1910 The Fatigue of Metals and New Methods of Testing. 'Génie Civil,' Oct. 22, 1910.

32 Frémont, C. 1910 Continuation of No. 31. 'Génie Civil,' Nov. 19, 1910.

Accidents caused by the fracture of steel and attributed to mysterious causes, notably fatigue, are in many cases due to bad quality of steel; *i.e.*, either bad quality generally, or local impurities.

See also Papers VIII. and X., International Congress for Testing Materials, 1912. See also Nos. 3, 23 and 94.

33 Gardener, J. C. 1905 Effect of Stress Reversals on Steel. 'Journ. Iron and Steel Inst.,' 67, 1905. 'Sci. Abs.,' 1905, No. 1804.

Quenched steel specimens submitted to alternating stress in a rotating-bar machine of cantilever (Wöhler) type. High resistance was found. This agrees with No. 65. See also No. 66.

34 Grimaldi, G., and Accolla, G. 1909 Influence of Oscillatory Discharge and of Magnetisation upon the Elastic Hysteresis for Extension of Iron. 'Elettricista, Rome,' 8, pp. 329–31. 'N. Cimento,' 18, pp. 446–77. 'Sci. Abs.,' 1910, 276.

35 Do. 1905 Influence of Magnetisation upon the Elastic Hysteresis for Extension of Iron. See 'Sci. Abs.,' A, 1905, 927.

36 Guye, C. E. 1912 Internal Friction of Solids, Variation with Temperature. 'Journ. de Physique,' 2 Ser. 5, Aug. 1912. 'Sci. Abs.,' A, 1912, 1793.

37 Guye and Mintz 1908 On Internal Friction of Solids at Low Temperatures. 'Archives des Sciences,' 26, pp. 136 and 263, 1908.

38 Guye and Friedericksz . 1909 Internal Friction of Solids at Low Temperatures. (Decrement of Torsional Oscillations.) 'Comptes Rendus,' 149, Dec. 6, 1909. 'Sci. Abs.,' 1910, No. 224. 'Comptes Rendus,' 150, April 18, 1910. 'Sci. Abs.,' 1910, No. 1189.

Note.—For Nos. 34, 35, 36, 37 and 38, see Report, Appendix I.

39 Do. 1912 Description of Krupp's Laboratory. (Mentions battery of six alternating-shock bending machines.) 'Revue de Métallurgie,' 9, 9, Sept. 1912.

The machines are on the principle of Stanton and Bairstow's alternating-shock bending machine (No. 78).

Notched specimens are used; the number of blows is 80 per minute. The machines are arranged to give, if desired, $\frac{1}{25}$ of a turn to the specimen after each blow. No results are given.

40 Haigh, B. P. 1912 Alternating Load Tests. 'British Association,' 1912. 'Engineering,' Nov. 29, 1912. 'Sci. Abs.,' 1912, No. 1612.

A description of the author's machine for testing wire in repeated tension. A few preliminary experiments only are recorded, the cycles having a frequency of 60 per second, and the stresses varying between 0 and a tensile maximum.

41 Hancock, E. L. 1906 Tests of Metals in Reverse Torsion. 'Phil. Mag.,' 12, pp. 426–30. 'Sci. Abs.,' A, 1906, 1810.

This paper is concerned with alterations of elastic limits by torsional overstrain in alternate directions of twist, the latter being slowly applied.

42 Haughton, S. A. 1905 Failure of an Iron Plate through Fatigue. 'Sci. Abs.,' A, 1905, 1846.

Failure of a barrel plate of a boiler. The plate had been exposed to severe 'panting' stresses.

43 Hopkinson, B. 1912 A High-speed Fatigue Tester and the Endurance of Metals under Alternating Stress of High Frequency. 'Proc. Roy. Soc.,' A, 86, Jan. 31, 1912. 'Sci. Abs.,' 1912, No. 628.

Description of the Hopkinson high-speed machine and of the checks on the calculated stresses. A variety of results given for speeds of 7,000 cycles per minute. It is conclusively shown that there is a very marked speed effect, both the number of cycles and the time required for producing fracture being greater than with machines at one or two thousand cycles per minute.

Table of Limiting Ranges of Stress, with Three Machines of Different Type for same Material.

Material	Stanton's Direct-stress Machine. 1,100 per minute	Wohler Rotating-bar Machine, N.P.L. 2,200 per minute	Hopkinson's Machine. 7,000 per minute
	tons per square inch	tons per square inch	tons per square inch
C	± 25	—	± 32
D	± 24	$\pm 26{\cdot}5$	$\pm 31{\cdot}5$

It is inferred that 'recovery of elasticity' is not an important factor in tests with equal ± alternations at high speeds, though at low speeds 'recovery' may be sufficient to mark the speed effect.

It is pointed out that it is not proved that the limiting range is higher, but that the apparent resistance to fatigue (in time and in number of cycles) is increased. The speed effect is shown to be the reverse of that found by Reynolds and Smith, No. 59.

Nos. 23, 65, 80, 82 and 84 show that speed effect is apparently negligible at speeds between 60 and about 2,400 cycles per minute.

44 Hopkinson, B., and F. Rogers 1905 Elastic Properties of Steel at High Temperatures. 'Proc. Roy. Soc.,' A, 76, 1905.

Tensile tests of iron and steel, using an extensometer, at temperatures up to 900° C. Tests not carried to fracture.

The elastic time effect (*i.e.*, that strain which occurs with lapse of time under a constant load, and which disappears with lapse of time upon removal of the load, as distinguished from hysteresis, which is independent of time) probably increases with temperature, since it was found to be very great at high temperatures.

45 Hopkinson, B., and Williams, G. T. 1912 The Elastic Hysteresis of Steel. 'Proc. Roy. Soc.,' Nov. 21, 1912.

See Report, Appendix I.

46 Howard, J. E. 1888 Watertown Arsenal Reports.
1893 See 'Massachusetts Institute of Technology.' 'Quarterly Proceedings,' 1899.

47 Do. 1906 Alternate Stress Testing and Heat Treatment of Steels. 'Engineering Record,' Sept. 22, 1906. 'Int. Assoc. Testing Materials Congress,' 1906. 'Sci. Abs.,' 1906, No. 1808.

Rotating loaded bar tests, at 500 r.p.m. Material, steels 0·17 to 0·82 % carbon. No steels were found to endure 100×10^6 rotations with greater stresses than ±40,000 lb. per square inch (calculated); but below this stress some bars withstood 150×10^6 rotations.

At 400° F. the endurance was rather greater than at 'atmospheric' temperature.

48 Howard, J. E. 1909 Resistance of Steels to Repeated Alternate Stresses. Paper read Intern. Assoc. Testing Materials, 1909. See also 'Mech. Eng.,' 24, Dec. 31, 1909. 'Sci. Abs.,' 1910, No. 218.

Rotating bar tests. Bars, 1 inch diameter, loaded to give uniform bending moment over 4 inches.

Speed, 500 r.p.m.

Material, 6 grades of open-hearth steel, hot rolled for commercial purposes; carbon content, 0·17 to 1·09 per cent.

Since the existence of or the possibility of finding a 'limiting range' of stress in rotating bar tests has been questioned the following results are quoted:—

0·55 per cent. C. Steel—

With ±35,000 lb. square inch rupture occurred with 9×10^5 rotations.

With ±30,000 lb. square inch rupture did not occur with 76×10^6 rotations.

0·82 per cent. C. Steel—

With ±45,000 lb. square inch rupture occurred with $6{\cdot}05 \times 10^5$ rotations.

With ±40,000 lb. square inch rupture did not occur with 202×10^6 rotations.

See also some results of Wöhler, page 378 Unwin's 'Testing of Materials.' Of the range of steels tested, the highest resistance was found for the 0·73 per cent. and 0·82 per cent. carbon. This agrees with Rosenhain's statement (No. 66), also substantially with Nos. 23, 62, 82, 90, 93. Occasional annealing at intervals during a test did not increase the endurance. See section Heat Treatment in Report.

The number of rotations necessary for fracture was much increased when the temperature of the test was 400° F. to 600° F., a result which differs somewhat from Unwin's (No. 91), and also from the author's own result in No. 47.

49 Kapp, G. 1911 Alternating Stress Machine. 'Zeits. Vereines Deutscher Ing.,' Aug. 26, 1911.

The stresses are direct tension and compression, and are obtained by the pull of an electro-magnet excited by an alternating current.

50 Lord Kelvin Article Elasticity, 'Ency. Brit.,' vol. vii., 9th ed.

51 Kommers, J. B. 1912 Repeated Stress Testing. Papers V. 4A and V. 4B., 'Intern. Assoc. for Testing Materials,' 1912. 'Sci. Abs.,' A, 1912, 1794.

Tests on a Landgraf-Turner machine. To and fro bending given by an oscillating die, the slot in the die being longer in the direction of the

stroke than the (unfixed) end of the specimen engaging with it. The length of the slot could be varied so as to give various proportions of impact (?) with the bending. The stroke of the die could also be varied.

Speeds, 150 to 700 (double) strokes per minute.

Specimens, $\frac{3}{8}$ inch diameter and $8\frac{1}{2}$ inch long.

The maximum stresses were higher than the tensile elastic limit.

Material, cold rolled steel, carbon 0·1 per cent., annealed at a red heat.

Within the limits of the experiments it was found that the endurance was independent of the proportion of the 'impact' factor in the bending. It is doubtful whether there was any dynamic effect at all at the moment of highest stressing. See Nos. 65 and 83. The nature of the surface of the specimen, whether turned, filed, or ground, had a marked effect. The polished and the ground specimens showed an increased resistance over the turned ones of 45 per cent. to 50 per cent. See also No. 23.

An attempt is made in a second paper (Int. Cong. for Testing Materials, 1912) to find the stresses in the above experiments by observation of the strains (beyond the elastic limit) and stresses in static bending tests, and of the strains and stresses in a tensile test of the same material.

52 Lenoble, E. 1900 Permanent Deformation of Metallic Wire (Hysteresis Loop). 'Journ. de Physique,' 9, Oct. 1900. 'Sci. Abs.,' 1901, No. 7.

A hysteresis loop was obtained for a wire which was gradually loaded and unloaded.

53 Lilly, W. E. 1910 A New Torsion-testing Machine. 'Proc. Inst. C.E. of Ireland,' Nov. 2, 1910.

A machine for direct and reverse torsion worked by hand; stress strain diagram automatically drawn.

54 Do. 1911 The Elastic Limits and Strength of Materials. 'Proc. Inst. C.E. of Ireland,' Dec. 6, 1911.

An account of some experiments on the machine of No. 53. The results are believed by the author to confirm Bauschinger's theory.

55 McCaustland, E. J. 1906 Effect of Low Temperature on the Recovery of Steel from Overstrain. 'Am. Soc. Min. Eng. Bull,' 9, May 1906. 'Sci. Abs.,' 1906, No. 1176.

The results are similar to those of No. 17.

56 Memmler, K., and Schob, A. 1910 Temperature Measurements during Repetition of Stress; experiments with Pipes. 'Kgl. Material-Prüfungs-amt. Mitt.,' 28, 6, pp. 307–33. 'Sci. Abs.,' A, 1910, 1382.

See Report, Appendix I.

57 Milton, J. T. 1905 Instit. of Naval Architecture, July 1905. Milton mentions cases of failure of plates by fatigue. Also 'Engineering,' Aug. 4 and 11, 1905.

58 Pearson, Karl 1905 On Torsional Vibrations in Axles and Shafts. 'Drapers' Company Memoirs,' Technical Series IV.

It is suggested that there may have been much higher stresses than those calculated in Wöhler's tests with ± alternate stresses, because the loadings were repeated before the stress-waves set up by the previous loadings had ceased to be of importance. Thus the real maximum stresses would be the sum of effects due to several successive loadings. Since L. Bairstow (No. 4) has obtained results corresponding quantitatively to Wöhler's (about 60 per minute), with a rate of loading of only two per minute, it seems probable that stress accumulation can only have been a very minor factor in Wöhler's results. Supposing a *small number* of successive peaks of stress to occur, the duration of the peak stresses would be very short and unlikely to give appreciable non-elastic strain (see No. 43); and moreover, though such non-elastic strain (cleavage slipping) may be produced, yet, unless the stresses producing these strains are many times repeated, cracking in the crystals would not be produced (No. 82). The fact of possible stress accumulation

cannot be ignored, and it is likely that some of the anomalous results of fatigue tests may be due to it. It is remarkable that Stanton's repeated shock tests (No. 83) should give results at least as consistent as those of tests in which the stresses are not (or are intended not to be) impulsive.

59 Reynolds, O., and Smith, J. H. 1902 On a Throw Testing Machine for Reversals of Stress. 'Phil. Trans.,' A, 199, 1902. 'Sci. Abs.,' 1903, No. 1302.

Two of the chief conclusions have been contradicted by subsequent work. These are:—

That under a given range of stress the number of reversals before rupture diminishes as the frequency of reversals increases. That 'hard' steels will not sustain more reversals with the same range of stress than mild steels when the frequency is high.

Some vibration of machine or specimen is supposed to be responsible for the above results. See remarks by Messrs. Stanton and Pannell, No. 84, pages 10 and 11.

60 Ritchie, J. B. 1910–11 Dissipation of Energy in Torsionally Oscillating Wires; Effects Produced by Change of Temperature. 'Proc. Roy. Soc., Ed.,' 31, 1910–11. 'Sci. Abs.,' 1911, No. 1310.

61 Do. 1910–11 Apparatus for Inducing Fatigue by Repeated Extensional and Rotational Strains. 'Proc. Roy. Soc. Edinburgh,' 31, 1910–11. 'Sci. Abs.,' 1911, No. 1311.

For Nos. 60 and 61, see Report, Appendix I.

62 Rogers, F. 1905 Heat Treatment and Fatigue of Steel. 'Journ. Iron and Steel Instit.' 1905. 'Sci. Abs.,' 1905, No. 1805.

Tests on rotating cantilever (Wöhler pattern) machine, 400 r.p.m. Three grades of steel tested.

See Report, note on 'Heat Treatment.'

63 Rogers, F. 1906 Microscopic Effects produced by the Action of Stresses on Metals. 'Soc. d'Encouragement Rev. de Metallurgie Mém.,' 3, Oct. 1, 1906.

Further details, with micrographs of the work of No. 62. Suggested reasons why slip lines in iron and steel should be 'broken.'

See Report, Note on Heat Treatment.

63a Rogers, F. 1913 So-called Crystallisation through Fatigue. Read before Iron and Steel Institute, September 1913.

64 Roos, J. O. 1912 On Endurance Tests of Machine Steel. Intern. Assoc. Testing Materials. Paper V. 2A, 1912.

65 Do. 1912 Some Static and Dynamic Endurance Tests. Intern. Assoc. Testing Materials. Paper V. 2B, 1912.

Two series of tests made on same material:—

(1) With rotating-bar machine of Wöhler type. Speeds, 1,200 and 2,400 r.p.m.

(2) In a machine of author's design. Blows were given by hammers striking a specimen alternately on either side. The maximum stresses were calculated from the height of fall of hammer, on the assumption that the whole energy of blow was taken up as elastic energy of the piece.

Material, steels of 0·10, 0·40, 0·65 per cent. of carbon, on which tests were made after 'annealing' and also after oil-tempering.

In (1) the endurance was rather higher with the higher speed.

In (1) and (2) the oil-tempered specimens had much greater endurance.

The 'f, n curves' for (1) and (2) corresponded very closely, confirming Stanton's (No. 83) result, that $\frac{f^2}{2E}$ may be taken as a measure of the resistance to repeated shock, f being the 'real' (natural) elastic limit.

66 Rosenhain, W. 1911 Two Lectures on Steel. 'Proc. Inst. Mech. Eng.,' Pt. II., pp. 280–83.

Remarks on resistance of steel to alternating stress.

67 Sankey, H. R. 1905 Vibratory Testing Machine. 'Mech. Eng.,' Nov. 11, 1905.

68 Do. 1907 Hand Bending Test. 'Engineering,' Dec. 20, 1907. 'Engineering,' Feb. 15, 1907.
See No. 10.

69 Schuchart, A. (Sen.) 1908 Resistance of Wire to Repeated Bending. 'Stahl und Eisen,' July 1 and 8, 1908.

Tests of wire, gripped in jaws with curved faces, over which the wire was bent backwards and forwards into contact with the faces.

70 1908 Olsen Vibrating Testing Machine. 'Elect. Rev., April 17, 1908.

71 1909 Landgraf-Turner Alternating Impact Machine. 'Iron and Steel Times,' June 24, 1909.
See No. 51.

72 Smith, J. H. 1905 Testing Machine for Reversals of Stress. 'Engineering,' March 10, 1905.

73 Do. 1909 Fatigue Testing Machine. 'Engineering,' July 23, 1909.

For direct stresses of any required range with any required mean stress of range. The specimen is motionless. The machine has been (or is being) used for various speeds of alternation.

74 Do. 1910 Experiments on Fatigue of Metals. 'Journ. Iron and Steel Instit.,' 2, 1910. 'Sci. Abs.,' 1911, No. 568.

Tests with machine of No. 73. Speed of repetitions, 1,000 per minute; various values, both + and −, of the mean stress being used. An extensometer was kept in position during the tests. A range of steels, of from 0·13 to 0·79 per cent. carbon content was tested; also some nickel steels. Most of the specimens were without heat treatment; a few were tested both in the untreated state and also after annealing.

The author proposes a new and very quick method of finding the Wöhler safe ranges. The validity of the method depends entirely on the experimental agreement between the Wöhler safe ranges, determined by the endurance test, and what the author calls 'yield ranges.' A description of the method of finding the latter is given in the paper. Very briefly, the 'yield range' is reached when the specimen first shows, by the extensometer indication, a small change of length, which appears to be similar to that found by Mr. L. Bairstow (No. 4), and called by him 'permanent extension.' It is shown, however, in No. 4, that these 'permanent extensions' may occur even if the range is a safe one. If Bauschinger's theory be accepted it is difficult to see why these 'yield ranges' should be the same as the Wöhler limiting (or safe) ranges. In Dr. Smith's method the successive changes of mean stress from + to − will give little opportunity for the adjustment of the elastic limits to the upper and lower limits of the range; whereas it is established that (Nos. 4, 7, and 82) such adjustment does take place when the range is in the neighbourhood of the safe range, and the mean stress is constant.

It would appear that before the method can be generally relied upon the experiments should be repeated, preferably on a machine of another type. The correspondence between the quickly determined 'yield ranges' and the Wöhler limiting range promises, however, to fulfil the need for a commercial substitute for the tedious Wöhler fatigue test.

75 Sondericker, J. 1899 Repeated Stresses. 'Massachusetts Inst. of Technology Quarterly Journ.,' 1899. (Description of machine, 1892, ditto.)

Machine of rotating-bar type, with constant bending moment over a short length. The materials tested were wrought iron and steels of carbon content 0·08 to 0·50 per cent., and the speeds 350 to 500 r.p.m. Two pointers were clamped to the part under uniform bending moment, and the extreme fibre strains measured; such measurements were taken at intervals during each test. The fibre stresses were high, often considerably above the observed

elastic limits in tension; but the latter appear to have had an unusually low ratio to the tensile strength. Thus:—

Specimen of Wrought Iron	Specimen of Steel
Range of stress $\pm 28{,}000$ lb. sq. in.	$\pm 42{,}000$
Rest (to fracture) $2{\cdot}5 \times 10^6$	(not broken) $3{\cdot}31 \times 10^6$
Tensile E. limit, 23,400 lb. sq. in.	38,300 lb. square inch
Tensile strength, 50,510 lb. sq. in.	78,010 lb. square inch

It is stated that the 'set' observed 'did not appear to have a notable influence in causing fracture until it reached ·001 inch or ·002 inch in a length of 10 inches.' Rest was found to decrease the 'set.' It was noticed that the specimens were always perceptibly warmer in the middle than near the ends. The temperature increased with the amount of the 'set.' Three specimens reached a blue heat (about 300° C.); the break occurred where the shaft was coolest.

The effects of a V groove and of a square shoulder were investigated. Some tests were made of flanged couplings, in which cracks commenced in the keyways.

76 Spangenberg 1874 Ueber das Verhalten der Metalle bei wiederholten Anstrengungen. See 'Handbook of Testing,' A. Martens, or Unwin's 'Testing of Materials.'

77 Stanton, T. E. 1905 Alternating Stress-testing Machine at the National Physical Laboratory. 'Engineering,' Feb. 17, 1905. 'Sci. Abs.,' 1905, No. 670.

An investigation concerning the effect upon the calculated stresses of the friction of the author's direct-stress reciprocating machine, and of the fluctuation of angular acceleration of the shaft.

78 Do. 1906 Repeated Impact-testing Machine. 'Engineering,' 82, July 13, 1906. 'Sci. Abs.,' 1906, No. 1520.

The specimen is ½ inch diameter, with V notch turned 0·40 inch diameter at bottom of V. It is placed on knife-edges 4½ inches apart, and receives blows over the notch from a tup, and it is given a half-revolution between each blow. Maximum speed, 100 blows per minute.

79 Do. 1907 A Factor in the Design of Machine Details. 'Engineering,' April 19, 1907.

On the effect of sudden changes of section in machine members, with estimates of the reduction of resistance to alternating stress.

80 Do. 1908 New Fatigue Test for Steel. 'Journ. Iron and Steel Inst.,' 76, 1908.

Test in simultaneous abrasion and fatigue. No speed effect was found for speeds between 200 and 2,200 cycles per minute.

81 Do. 1912 Recent Researches made at the National Physical Laboratory on the Resistance of Metals to Alternating Stress. Intern. Congress for Testing Materials. Paper V. 1, 1912.

82 Stanton and Bairstow 1905 On the Resistance of Iron and Steel to Reversals of Direct Stress. 'Proc. Inst. Civ. Eng.,' clxvi. 'Sci. Abs.,' 1907, No. 373.

Tests made on commercial materials of iron and steel, using Stanton's direct-stress machine (No. 77); cycles 800 per minute, the ratio

$$\frac{\text{maximum tensile stress of cycle}}{\text{maximum comp. stress of cycle}}$$

being from 1·4 to 0·72.

Results:—

No reduction in endurance was found at 800 per minute as compared with 60 per minute, thus agreeing with Nos. 23, 43, 65 and 80.

High carbon steels have superior endurance, thus agreeing with Nos. 23, 48, 62, 90, 93.

The effect of 'rate of change' of section of test pieces demonstrated, and the endurance of various forms (screwed, &c.) compared. See Nos. 23, 74, 75 and 93.

Strong evidence was found that the primitive elastic limits are frequently unstable under alternating stress; also evidence concerning the coincidence of the Wöhler limiting range and the 'natural' elastic ranges. See also, notably, No. 4.

Fracture occurs by cracking in one of the localities where slip bands are massed together. Fracture goes through ferrite crystals, not only in iron (No. 27), but also in medium carbon steels. This is in accordance with Nos. 62 and 63. See also No. 66.

The mode of fracture is the same whether the stress is applied directly or by means of bending (Nos. 62, 63).

83 Stanton and Bairstow 1908 The Resistance of Materials to Impact. 'Proc. Inst. Mech. Eng.,' No. 4, 1908.

A machine for giving alternating direct impact is described. The blows of a tup put the specimen into alternate tension and compression. One of the chief objects of the research was to determine the limiting resistance of the materials for which the resistance to alternating stress had already been found. The important conclusion is reached that, if f is the 'real' elastic limit derived from the Wöhler test, then the measure of the resistance to repeated small $\pm$ equal impacts is $\frac{f^2}{2E}$. This result is confirmed by Roos (No. 65). See also No. 51.

84 Stanton and Pannell 1911 Experiments on the Strength and Fatigue Properties of Welded Joints in Iron and Steel. 'Proc. Inst. Civ. Eng.,' vol. clxxxviii., 1911.

85 Stead and Richards 1903 Sorbitic Steel Rails. 'Iron and Steel Inst. Journ.,' 1903, II., p. 141.

Mentions rotating-bar (Wöhler type) tests on rails specially heat-treated.

86 Do. 1903 Restoration of Dangerously Crystallised Steel by Heat Treatment. *Ibid.*, p. 119.

Rotating-bar tests and heat treatment.

87 Do. 1905 Overheated Steel. Heat Treatment; tests in Wöhler machine, and also in severe bending.

88 Thearle, S. J. P. 1913 Note on some Cases of Fatigue in the Steel Material of Steamers. Inst. Naval Arch., June 1913. Also 'Engineering,' June 27, 1913.

89 Tobusch, H. 1908 Elastic and Magnetic Hysteresis. 'Ann. de Physik.,' 26, 3. 'Sci. Abs.,' A, 1908, No. 1482.

See Report, Appendix I.

90 Turner, L. B. 1911 The Strength of Steel in Compound Stress and Endurance under Repetition of Stress. 'Engineering,' July 28 to Sept. 8, 1911. 'Sci. Abs.,' 1911, No. 1315.

Bending Tests on cantilever specimens; one end fixed, the free end being made to describe a circle of constant small radius.

Torsion Tests.—One end fixed, the other end twisted to and fro through a constant small angle.

Speed, 250 cycles per minute.

Materials.—Tube steel (annealed and untreated), mild steel, tool steel, and nickel steel (annealed and untreated).

The main object of the research was to determine how far the shear-stress criterion of elastic failure applies to alternating-stress tests. The tests gave an affirmative result for tube steel and mild steel for both tension and torsion, and a negative result for tool steel and nickel steel.

91 Unwin, W. C. 1905 Experiments on Rotating Bars at Different Temperatures. 'Proc. Inst. Civ. Eng.,' clxvi. 'Sci. Abs.,' 1907, No. 373.

Rotating cantilever tests in which mild steel appeared to have slightly greater endurance at 400° to 500° F. than at ordinary temperatures. J. E. Howard (No. 48) finds that the number of rotations for fracture was very much increased at temperatures of 400° F. to 600° F. This is partly a metallurgical question, as the condition of the steel previous to the warming may affect the result. Further, it is known that the elongation in tensile tests of the steels dealt with would be slightly improved at the temperatures named, which is broadly in agreement with these authors' results.

92 Unwin, W. C. — General Considerations on Safe Working Limits of Stress. 'Testing of Materials of Construction,' Art. 255, 1910 edition.

93 Wöhler, A. 1871 Ueber die Festigkeitsversuche mit Eisen und Stahl. See 'Engineering,' vol. II., or Unwin's 'Testing of Materials.'

94 (Various writers) 1910 Enquête sur la fatigue des Métaux. 'La Technique Moderne,' 1910, vol. 2, pp. 19–21, 83–84, 151–4, 210–4, 280–4, 345–7.

Discussion of these questions, proposed by the Editors:—

1. Is it established that metals undergo, in time, fatigue which noticeably alters their endurance ?

2. Are the circumstances of this known and can they be avoided ?

3. Are there means of recognising the symptoms of this state, and hence avoiding disasters resulting from it ?

4. What inferences can be drawn from the existence of these phenomena from the point of view of determining the safety of metallic machines and structures ?

The replies received are generally of the utmost vagueness, or are quite platitudes to all concerned materially in the subject, or are of little practical bearing (*e.g.*, most of Retjo's theory).

A. Mesnager quotes *Le Chatelier* (Internat. Congr. for Testing Materials, 1900, p. 90) that an alteration of the decrement would be produced by alteration of the material, and seems to suggest this as an indication of the progress of fatigue in a piece. [Evidently this would rarely be applicable.—F. R.]

P. Breuil refers to the fact that the vastly greater part of the work on the subject is British, both combined stress and alternating. Eighty per cent. of the failures are due to ignorance on the part of the designer (as to stress which will actually come upon the piece). It is not known whether any stress, however small, will produce a permanent deformation, or, if so, whether this deformation is local only. The microscope is the best instrument at present available in this respect. It is necessary to do fatigue tests above the elastic limit, and desirable to register deformation at each alternation of the same stress, or to register each load necessary to give equal alternating deflections. Importance of hysteresis. Importance of annealing to restore from the effects of fatigue ; but this is not always practicable.

F. Schule.—Microscope has not given a satisfactory answer to (2).

Do.—Suggests electric conductivity should be tried as a test for progress of fatigue for (3).

(This is of very little use.—F. R.)

4. Suggests scrapping after a certain life ; *i.e.* 'life' factor of safety.

A. Retjo.—Treats the subject mathematically, following Van der Waals and Amagat.

L. Grenet.—It is not fully evident that annealing will restore fatigued material.

(Of course not. Qualification is necessary. See comment below.—F. R.)

In design, so far as possible, it should be endeavoured to calculate the shock absorbable ; in general, he recognises the importance of resilience ; he suggests particularly *tests of the safe limit of repeated shock,* accompanied by the use of a large factor of safety.

Cellerier and Breuil.—Report on a broken rail. Failure ascribed to fatigue of the intensely cold-worked (in service) surface layer.

L. Guillet.—Troubles are usually due to bad treatment of metals. His answer to (3) and (4) is 'Prudence.'

Comments by F. Rogers.

It is worth noting at the outset that, rather differently from us, the French often mean by 'fatigue' what we would call simple overstrain; *e.g.*, such as occurs in a tensile test piece strained beyond the elastic limit. In this particular series of articles, however, this use of the term has not occurred considerably. Further, there seems to be no reference to any question of an 'ageing' effect in metals, either under steady stress or in the absence of stress.

Most writers, as is to be expected, agree explicitly or implicitly in answering (1) in the affirmative.

There is no agreement as to *unconditional scrapping* after a specified life (measured in time, or else number of stressings). This is as one would expect, since in most cases the aim is to design for permanent use, except where *unavoidable wear* is concerned. Railway cranks and axles are, however, used for a definite mileage only.

I consider that the suggestions made by *Grenet* are the crux of the problem, although they are not individually novel. There is room for more research on resilience from this point of view, particularly the values of elastic modulus in relation to endurance of repeated stress and repeated shock, and the safe limit of repeated shock.

I have shown (No. 62) the increase of elastic modulus with brittleness due to overheating of steel.

Periodical annealing during the useful life is only applicable to certain materials and to certain forms. No large pieces, such as shafts, can be so dealt with, on account of distortion and scaling. Small iron articles, such as chains, are annealed. I have shown that at a certain stage annealing is in any event incapable of restoring a material. The original heat treatment of steels is often such that their properties would be hopelessly ruined by any process which could fall under the vague term 'annealing.' Springs are, however, sometimes annealed and re-tempered; it is questionable whether any advantage is gained.

The microscope is a valuable aid to research, but it is only in exceptional cases that it is of assistance in finding hair-cracks in existing structures. In my experience the hair-crack period is of short duration, and tests to destruction are the most reliable index of the state of the material; but in certain cases it would be worth while to keep vital points polished ready for periodical examination (and varnished), and approaching fatigue could then be satisfactorily detected at a considerably earlier stage than the appearance of hair-cracks.

In regard to Guillet's dictum that the original treatment of the metal is usually to blame when metals fail under alternating stress, I do not think it is possible to arrive at a general conclusion; that is to say, each of the following three main classes contain the usual sources of trouble, and many cases in practice have been traced to each of these causes:—

(*a*) *Flaws*, including pipe, fissures, blow-holes, impurity, and non-metallic enclosures.

(*b*) *Faulty original heat-treatment* of pure metal. This includes, as a special case, strains set up in manufacture, and overwork in the working processes.

(*c*) *Under-estimation of stresses* to be expected on the part of the designer. This includes, as a special case, insufficient allowance for the effect of repetition of a stress which would be harmless if applied once or steadily maintained.

SPECIAL PROBLEMS.

The Resistance of Tubes to Collapse. By GILBERT COOK, *M.Sc.*

(The small figures in the text refer to the bibliography.)

When a thin cylindrical tube is subjected to a gradually increasing external pressure, a point is reached at which the equilibrium becomes unstable, any further increase in the pressure resulting in the collapse of the tube. This pressure is known as the collapsing pressure. The subject of its determination is one which has, from time to time, received considerable attention both from mathematicians and engineers. Yet, in spite of the

practical importance of the subject, definite and exact knowledge is lacking. A universal formula has not yet been found by which the strength of a tube of given dimensions and material may be estimated. It is perhaps safe to say that it is impossible to devise such a formula which will be sufficiently simple to be of any practical value. This will at once be evident when the number of factors which enter into the problem, and the lack of knowledge with regard to each, irrespective of their mutual relations, are considered. These factors may be divided into two main classes: (*a*) those relating to dimensions and geometrical form; (*b*) those relating to the physical properties of the material. The first of these may be subdivided as follows:—

(1) Lateral dimensions; *i.e.*, diameter and thickness.

(2) Length.

(3) The boundary conditions at the end of the tube.

The statical condition of the tube at the moment of collapse being one of unstable equilibrium, the influence of slight variations from the circular form or uniform thickness which are invariably found in practice must also be considered.

It is proposed in the course of this report to consider separately the influence of the above factors.

Lateral Dimensions.

Although the influence of length will be dealt with later, it may be stated here that it is found both from experiment and theory that, as the length increases, the strength of a tube of given lateral dimensions tends to a minimum constant value, which appears to be attained, for practical purposes, when the length is greater than six times the diameter.[5, 19] It is therefore proposed to consider here only the case of a tube of infinite length. The strength of such a tube is dependent upon its diameter and thickness, and it appears to be established, both from theoretical considerations and from the experimental data available, that the collapsing pressure is some function of the ratio of the thickness to the diameter $\left(\frac{t}{d}\right)$. A complication is at once introduced by the fact that the form of that function depends upon the value of the ratio $\frac{t}{d}$.

The problem is, in many respects, analogous to that of a column under a direct compressive load, in which the conditions determining failure depend on the ratio of k, the least radius of gyration of the cross-section, to l, the length. In the failure of a column, two ranges of values of $\frac{k}{l}$ may be distinguished.

(1) When $\frac{k}{l}$ is very small, failure occurs by pure buckling, without any departure from perfect elasticity, and it can be deduced mathematically that the stress at failure is

$$p = a\left(\frac{k}{l}\right)^2$$

where a depends only on Young's modulus and the end conditions.

(2) When $\frac{k}{l}$ exceeds a certain fairly definite value, failure is caused by

the elastic breakdown of the material in some part of the column. If the ratio is not too great, buckling results from irregularities thus produced, and the problem is not amenable to rigorous mathematical treatment owing to the fact that such inequalities are largely the result of initial irregularities in the form of the column.* When, however, $\frac{k}{l}$ becomes large, buckling does not occur, and failure takes the form of uniform lateral expansion.

There is an analogy in the collapse of tubes to each of these cases.

(1) When the ratio $\frac{t}{d}$ is very small, collapse will occur without over-strain in any part of the material. As in the case of long columns, this is the only case for which a complete mathematical solution has been found. The problem was first investigated by Bryan,[4] and the theory subsequently improved by Basset [1] and Love,[12] and more recently by Southwell. [17, 18] The pressure at which the equilibrium becomes unstable is given by

$$p = c\left(\frac{t}{d}\right)^3 \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where c is a constant depending only on the elastic properties of the material, and is equal to

$$\frac{2\ E}{1-m^2}$$

where E is Young's modulus, and m Poisson's ratio.

Very elaborate and accurate experimental work carried out during recent years by Carman[6] and Stewart[19] has shown that the relation (1) holds very nearly in the case of tubes in which the ratio $\frac{t}{d}$ is less than ·025. The value of the constant c is, however, found to be considerably less than the theoretical value. The discrepancy has been attributed by Slocum[16] to imperfections in the geometrical form of the tube, and by Southwell to the fact that in the comparison of the theoretical and experimental results, values of $\frac{t}{d}$ were included which were great enough to allow elastic breakdown to precede instability.

(2) When the ratio $\frac{t}{d}$ exceeds ·025, it is found by experiment that the relation (1) no longer holds. It is evident that no tube can withstand, without permanent deformation, a pressure greater than that which would cause any part of the material to exceed the elastic limit. By Lamé's theory the maximum compressive stress occurs at the inner surface of the tube, and, assuming that there is no longitudinal constraint, is given by

$$f = \frac{p}{2\left(\frac{t}{d} - \frac{t^2}{d^2}\right)}$$

* It is possible to give a mathematical explanation of the *form* of the curve showing the relation of load to $\frac{k}{e}$ even in this case. See paper by R. V. Southwell, 'The Strength of Struts,' *Engineering*, Aug. 23, 1912.

and therefore the maximum pressure which could be applied to the tube without permanent deformation is theoretically

$$p = 2f_1 \left\{ \frac{t}{d} - \frac{t^2}{d^2} \right\}$$

where f_1 = direct compressive stress at yield. How far the strength of the material in compression does actually enter into the problem does not appear to have been satisfactorily determined. It is probable that for a certain range of the ratio $\frac{t}{d}$ upwards from ·025 the tube does not fail either by simple buckling or by direct crushing, but by a combination of both. It is found that the results of tests on tubes of this form may be conveniently expressed by the relation

$$p = a\left(\frac{t}{d}\right) - b$$

where a and b are constants depending on the material.[6, 19] The upper limit of the ratio $\frac{t}{d}$ for which this relation holds has not been determined, but its maximum value in the tests upon which it is based was about ·07.

A question of some interest is the value of $\frac{t}{d}$ for which collapse in the form of buckling ceases to occur. Recent experiments by Bridgman[3] have shown that the effect of the application of high hydrostatic pressure to tubes of ductile materials in which the ratio of thickness to external diameter is greater than 0·27 is to close up the hole in a uniform manner, without any departure from the circular form.

Length.

Very little experimental data are available in regard to the influence of the length upon the strength of a tube to resist collapse. Indeed, the attention paid to this point has not been in any degree commensurate with its importance.

Recent experimental work has shown that when the length is sufficiently great it ceases to have any appreciable effect upon the strength. An attempt has been made to define the length below which the strength is materially increased, and the term 'critical length' has been applied to this quantity by Love and Carman. Such a term suggests a point of discontinuity, the existence of which, in the above sense, is hardly conceivable. An investigation by Love,[12] based partly on analysis, and partly on analogy to simpler problems, leads to the result that, for thin tubes of different lateral dimensions, the influence of the length becomes negligible to the same order when it is greater than some multiple of the mean proportional of the diameter and thickness; *i.e.*, when

$$l > \alpha\sqrt{dt} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where α is a constant.

An important contribution to the theory of this subject recently made by Southwell[17, 18] has pointed to the desirability of a modification in the meaning attached to the term 'critical length.' It is a well-known fact that the number of lobes into which a tube collapses is dependent upon the

length of the tube; the shorter the tube, the greater is the number of lobes. Unwin [22] was the first to appreciate the importance of this fact, and he used it in an attempt to set on a more rational basis the results of the classical experiments of Fairbairn.[8] Southwell has shown, however, that the collapsing pressure of any tube in which the ratio $\frac{t}{d}$ is very small may be expressed by

$$p=2E\frac{t}{d}\left[\frac{Z}{\kappa^4(\kappa^2-1)}\frac{d^4}{l^4}+\frac{1}{3}\frac{\kappa^2-1}{(1-m^2)}\frac{t^2}{d^2}\right]$$

where κ is the number of lobes in the collapsed cross-section and Z is a constant depending on the type of the end constraints. If, for a tube of given thickness and diameter, the value of p be plotted against l for values of κ equal to 2, 3, 4 . . . . a series of curves is obtained; and Southwell has pointed out that, from an inspection of these curves, it will be seen that long tubes will always tend to collapse into the two-lobed form, since the curve for $\kappa = 2$ then gives the least value for the collapsing pressure, but that at a length corresponding to the point at which this curve intersects the curve for $\kappa = 3$, the three-lobed form becomes natural to the tube, and for shorter lengths still, for which the point of intersection of the curves for $\kappa = 3$ and $\kappa = 4$ gives the upper limit, the four-lobed form requires least pressure for its maintenance. Thus the true curve connecting pressure and length is a discontinuous one, and therefore the collapsing pressure is not a continuous function of the length.

It may be suggested therefore that the term 'critical length' be applied to the points of discontinuity; that is, the points of intersection of the curves for $\kappa = n$ and $\kappa = n + 1$, these points being rightly described as 'critical' in the sense that the tube may collapse into either n or $n + 1$ lobes at these points. With this meaning a tube will have a number of critical lengths corresponding to the configuration of the collapsed cross-section, and it may be shown that for different tubes the length corresponding to the critical points is proportional to

$$\sqrt{\frac{d^3}{t}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Southwell has pointed out that the above expression is also the factor determining the value of the critical length in the sense in which that term has been generally used, *e.g.*, by Love and Carman. Prof. Love has accepted the above result as superseding the expression (2) given above.

It would appear from (3) that a thin tube may collapse into a greater number of lobes than a thicker tube of the same length and diameter. This has been verified in experiments carried out by the writer, but beyond this no definite experimental confirmation of the above results has yet been made, although work in this direction is in progress. It has usually been assumed—and the assumption appears to be sufficiently justified by the experimental work of Carman and Stewart—that, for practical purposes, the influence of the length vanishes when it exceeds about six diameters, and that below this value the strength of the tube may roughly be taken as proportional to the reciprocal of the length, although the experimental evidence in regard to the latter cannot be regarded as conclusive.

End Conditions.

In dealing with the question of length no assertion was made in regard to the statical conditions at the ends of the tube. In the experimental work the ends were rigidly fixed to a true circular form of invariable diameter, and were also held rigidly in a longitudinal direction. Southwell has shown [17] that any variation in these conditions in the case of a short tube will considerably affect the resistance to collapse. It is reasonable to suppose that where the ends are more or less flexible in any direction, the strength will not be as great as when the tube is rigidly held parallel and circular. It is, however, hardly to be expected, when the knowledge of the general effect of length is so vague, that the effect of the end conditions could be expressed in more exact terms.

Variations from True Geometrical Form.

The ideal conditions assumed in the derivation of the rational formula are never realised in practice. The phenomenon of collapse is, however, due to imperfections in form and material, and, in the mathematical analysis of the ideal case, the collapsing pressure is that which would produce a state of neutral equilibrium in the shell, although actual collapse would only occur if some slight unsymmetrical deformation were caused. It is evident that slight initial deviations from the perfect form must affect the value of the collapsing pressure to a considerable extent. The earlier experimental work in this subject by Fairbairn [8] was carried out on tubes which were lap-riveted and in which therefore the variation from the true circular form was at least equal to the thickness of the plate. Although serving the purpose for which they were intended at the time, the results have little application to modern tubes, which are either solid drawn or welded, and are much more perfect in form. The slight variations, however, which still occur are probably responsible in a large measure for a considerable departure from the theoretical strength. Experiments carried out within recent years on modern tubes have shown that the relation

$$p = c\left(\frac{t_1}{d_1}\right)^3,$$

where t_1 and d_1 are the average thickness and diameter, holds when the average of a large number of tests is taken, but the constant is smaller than the theoretical constant by about 30 per cent. Further, wide differences in the collapsing pressure of tubes of the same average dimensions have frequently been found. A theoretical formula for the calculation of the effect of inequalities in diameter and thickness is hardly to be looked for, even if it were possible or convenient to measure the latter, for any given tube. Such a problem is, moreover, complicated by the fact that the positions of greatest and least thickness may have any relation to those of greatest and least diameters, with a corresponding variation in the combined influence.

A series of tests was carried out by Stewart [20] some six years ago on steel tubes 10 inches in diameter in order to determine the effect of distortion on the collapsing pressure. It was found that the results could be expressed by the formula

$$p_2 = 0\cdot0926\,\frac{p_1 - 47\cdot55}{(\mathrm{M} - 0\cdot874)^{1\cdot25}} + 47\cdot55$$

where p_1 = collapsing pressure of normally round tube (in lbs. per sq. in.).
p_2 = collapsing pressure of distorted tube.
M = ratio of maximum to minimum diameter.

The utility of this formula is, however, somewhat doubtful, and cannot in any case be taken as indicating the effect of initial deviations from the true circular form, since p_1 is the experimentally determined collapsing pressure of what is described as 'a normally round tube,' which in this case was merely a commercial tube of average quality.

It has since been proposed by Slocum[16] that the rational formula may be made applicable to the practical determination of the collapsing pressure by introducing a correction factor, C, so that

$$p = C \cdot \frac{2\,E}{1 - m^2} \left(\frac{t_1}{d_{max}}\right)^3$$

where t_1 is now the average thickness and d_{max} the maximum diameter. The assumption that the strength varies as the cube of the ratio of the average thickness to the maximum diameter is not entirely valid, but it has been found that the above formula gives a fairly close approximation, and that C is nearly constant for any one class of tubes. Its value has been found for the following cases, the tubes in each instance being of average quality:—

1. Lap-welded steel tubes = ·69.
2. Solid-drawn weldless steel tubes = ·76.
3. Solid-drawn brass tubes = ·78.

The values of E and m are known for most materials, and the maximum diameter and average thickness are the dimensional quantities most readily and conveniently obtainable for a given tube. It is, however, somewhat doubtful whether variations from true geometrical form would account altogether for the reduction of 25 per cent. to 30 per cent. indicated above. Southwell considers that too wide a range of values of $\frac{t}{d}$ were used in the comparison, and that in the thicker tubes the elastic limit of the material was reached before the equilibrium became unstable, thus producing a lower value of the collapsing pressure.*

Physical Properties of the Material.

It is evident, from statical considerations, that the whole of the material composing a tube of circular form is in a state of compression in a circumferential direction. The physical properties which it is natural to suggest as determining the strength are Young's modulus, the elastic limit, and, for thick tubes, the ultimate strength, all in compression. The two latter quantities are difficult to determine, and the ultimate strength, in materials usually employed in tubes, is a somewhat indefinite quantity. The value of Young's modulus is known to be approximately the same in compression and tension, and is easily determined. For thin, long tubes it appears to be the only physical property influencing the resistance to collapse. The custom of specifying, as in the case of boiler flues, the ultimate tensile strength cannot therefore have any reference to the actual collapsing pressure, but serves merely as a guarantee of the quality of the

* This question is fully discussed by Mr. Southwell in a paper which is to appear in the *Philosophical Magazine* for September 1913.

material employed. The elastic limit in compression enters into the problem when the thickness is considerable, and also when the length is short. The precise influence of the ultimate strength is not known, and the uncertainty in regard to its value would render futile any attempt to introduce it.

In conclusion, it may not be out of place to make a few general remarks in regard to the practical side of the question. Few problems in engineering have given rise to a larger number or greater variety of formulæ, and it is not surprising that in actual practice the design of tubes to withstand external pressure is based upon previous experience obtained from failures of tubes of the same material and dimensions rather than upon theory or even systematic general experimental work. In the case of boiler flues, the rules formulated by the Board of Trade [25] and Lloyds' [26] differ, but are based upon the same tests carried out upon flues of the same form as those to which they are intended to be applied, and are admittedly inapplicable beyond the range of these tests. In these formulæ, which stipulate the safe working pressure, and not the collapsing pressure, allowance is made for effects such as corrosion, associated with the particular purpose for which the tubes are used.

The case of long, thin, plain tubes, such as are employed for smoke tubes in locomotive boilers, appears to be the only one for which it is possible to propose a general and useful formula. The most convenient appears to be that obtained by introducing into the rational formula a constant depending only upon the material and mode of manufacture, and not on the absolute size. It has been suggested by Slocum[16] that the most useful purpose likely to be served by further experimental work is the determination of the factor for different kinds of tubes. This was proposed some four years ago, but the difficulty and expense of systematic experimental work of this character has limited the investigation to three classes of tubes only.

Bibliography.

1 Basset, A. B. 1892 On the Difficulties of Constructing a Theory of the Collapse of Boiler Flues. 'Phil. Mag.,' 1892, vol. 200, p. 221.

2 Belpaire, T. 1879 Note on the Resistance of Tubes to External Pressure. 'Annales du Génie Civil,' March 1879.

The formula

$$p = 3{,}427{,}152\frac{t^2}{ld} - 56{,}892{,}400\frac{t^3}{ld^2}$$

is given as representing the results of Fairbairn's tests.

3 Bridgman, P. W. 1912 The Collapse of Thick Cylinders under High Hydrostatic Pressure. 'Physical Review,' vol. xxxiv., No. 1. Jan. 1912. 'Sci. Abs.,' 1912, No. 427.

4 Bryan, G. H. 1888 Application of Energy Test to Collapse of Long, Thin Pipe under External Pressure. 'Proc. Camb. Phil. Soc.,' vol. vi., p. 287. 1888.

Gives the derivation of rational formula

$$p = \frac{2E}{1 - m^2} \cdot \frac{t^3}{d^3}$$

5 Carman, A. P. 1906 Resistance of Tubes to Collapse. 'Physical Review,' vol. 21, Dec. 1905, pp. 381–387. 'Sci. Abs.,' 1906, No. 239.

Describes a series of tests on small brass tubes, diameters ranging from

·891 to 1·78 cm.; thickness from ·041 to ·135 cm. Length from 8 mm. to 210 mm. Results seemed to indicate that when length > 6 diameters, strength practically constant. Below that length, strength appeared to be inversely proportional to length, though it is stated that experiments are not sufficient to determine definitely the relation.

6 Carman, A. P., and Carr, M. L. 1906 Resistance of Tubes to Collapse. 'Univ. of Ill. Bull.,' vol. 3, No. 17, June 1906. 'Sci. Abs.,' 1906, No. 1986.

Describes tests carried out on a number of lap-welded steel tubes, seamless cold-drawn steel tubes and brass tubes.

Following formulæ are given :—

(a) When $\frac{t}{d}$ less than ·025

$$p = 25{,}150{,}000\left(\frac{t}{d}\right)^3 \text{ for brass tubes.}$$

$$p = 50{,}200{,}000\left(\frac{t}{d}\right)^3 \text{ for seamless steel tubes.}$$

(b) When $\frac{t}{d} > 0{\cdot}03$

$$p = 93{,}365\,\frac{t}{d} - 2{,}474 \text{ for brass tubes.}$$

$$p = 95{,}520\,\frac{t}{d} - 2{,}090 \text{ for seamless cold-drawn steel.}$$

$$p = 83{,}270\,\frac{t}{d} - 1{,}025 \text{ for lap-welded steel.}$$

The last formula in each series agrees well with those obtained by Stewart.

7 Clark, D. K. Strength of Boiler Flues. 'Engineering,' vol. 46, p. 280.

From reports of Manchester Steam Users' Assoc. of six boiler-flues actually collapsed, gives formula

$$p = t^2\left(\frac{50{,}000}{d} - 500\right)$$

8 Fairbairn, W. 1858 Resistance of Tubes to Collapse. 'Phil. Trans.,' 1858, p. 389. 'Brit. Assoc. Report,' 1857, p. 215.

Tests carried out on 32 wrought-iron tubes, lap-riveted, varying in diameter from 4 to 12 inches and in length from 1 foot 3 inches to 5 feet. Uniform thickness except in five cases, ·043 inch. Results of tests represented by formula

$$p = 9{,}675{,}600\,\frac{t^{2\cdot 19}}{l.d}$$

(p in lbs. square inch, t, l, d in inches).

9 Grashof, F. 1859 W. Fairbairn's 'Versuche über den Widerstand von Rohren gegen Zusammendruckung.' 'Zeitschr. des Vereines deutscher Ingenieure,' 1859, p. 234. Todhunter and Pearson, 'History of Elasticity,' vol. ii. p. 1; i., p. 666.

From Fairbairn's tests, deduces formulæ

$$(a)\ p = 1{,}033{,}620\,\frac{t^{2\cdot 081}}{l^{\cdot 564}\,d^{\cdot 889}} \text{ for thin tubes.}$$

$$(b)\ p = 24{,}481{,}000\,\frac{t^{2\cdot 315}}{l.d^{1\cdot 278}} \text{ for thick tubes.}$$

Also considers a tube of slightly elliptical cross-section, and, using a method previously suggested by Bresse, obtains the formula

$$p = \frac{2\,C\,\frac{t}{d}}{1 + \frac{3e}{2}\,\frac{d}{t}}$$

Where C_0 = compressive strength,
e = ellipticity,
d = diameter of circular tube of same circumference as ellipse.

10 Lilly, W. E. 1910 The Collapsing Pressure of Circular Tubes. 'Proc. Inst. Civ. Eng. of Ireland,' Feb. 2, 1910.

The analogy of the problem of tube collapse to failure of columns is discussed, and a formula similar to the Rankine-Gordon formula is derived, viz.

$$p = \frac{2f}{\frac{d}{t} + \frac{f}{nE} \cdot \frac{d^2}{t^2}}$$

where f = strength to compression, and n is a constant to be determined experimentally.

The investigation is also extended to corrugated flues.

11 Lorenz, R. 1911 Buckling of Thin-walled Cylinders. 'Phys. Zeitschr.' n. 12, pp. 241–260. April 1911. 'Sci. Abs.,' 1911, No. 978.

12 Love, A. E. H. 'Mathematical Theory of Elasticity,' p. 530.

The theoretical formula

$$p = \frac{2E}{1 - m^2} \frac{t^3}{d^3}$$

is given, and it is shown that when the pressure exceeds this limit, any flue will collapse if its length exceeds a certain multiple of the mean proportional between the diameter and thickness.

13 Love, G. H. 1859 Sur la résistance des conduits intérieurs à fumée dans les chaudières à vapeur. 'Mémoires et Comptes Rendus,' 1859, pp. 471–500. Todhunter and Pearson, 'History of Elasticity,' vol. ii., pt. 1, p. 667.

The formula

$$p = 5{,}358{,}150\frac{t^2}{ld} + 41{,}906\frac{t^2}{d} + 1{,}323\frac{t}{d}$$

is given as representing the results of Fairbairn's experiments.

14 Nystrom, J. W. 'Treatise on Steam Engineering,' p. 106.

Derives the formula

$$p = 692{,}000 \frac{t^2}{l^{0.5}d}$$

as representing results of Fairbairn's tests.

15 Roelker, C. R. 1881 Experimental Investigation of Resistance of Flues to Collapse. 'Van Nostrand's Magazine,' vol. 24, p. 208.

16 Slocum, S. E. 1909 Collapse of Tubes under External Pressure. 'Engineering,' Jan. 8, 1909, vol. 87, p. 35.

A discussion of Carman's and Stewart's experiments. Suggests that discrepancy between theoretical formula and experimental results due to imperfections in geometrical form. Proposes the introduction of a 'correction factor' C in the formula, thus:

$$p = C \frac{2E}{1 - m^2} \left(\frac{t}{D}\right)^3$$

Following values of C are given:
Lap-welded steel tubes C = ·69.
Solid-drawn weldless steel tubes C = ·76.
Solid-drawn brass tubes C = ·78.

17 Southwell, R. V. 1913 On the General Theory of Elastic Stability. 'Phil. Trans.' (A), vol. 213 (1913), pp. 187–244.

Discusses the boiler-flue problem as an example to illustrate a proposed

new method of rigorous investigation for stability problems in general. It obtains the general formula

$$p = 2E\frac{t}{d}\left[\frac{\lambda^4}{\kappa^4(\kappa^2-1)}\cdot\frac{d^4}{16}+\frac{1}{3}\cdot\frac{\kappa^2-1}{1-m^2}\cdot\frac{t^2}{d^2}\right]$$

where κ = number of lobes in collapsed cross-section and $\frac{1}{\lambda}$ is proportional to the length of the flue, the ratio depending on the terminal conditions. It is shown that the above formula leads to a result differing from that of Prof. Love (see No. 12) for the rate of decay of end effects.

18 Southwell, R. V. 1913 On the Collapse of Tubes by External Pressure. 'Phil. Mag.,' May 1913.

An attempt to meet the difficulties suggested by A. B. Basset. (See No. 1.) An investigation of the strength of short tubes is also given leading to the formula given in No. 17.

19 Stewart, R. T. 1905–6 Collapsing Pressures of Bessemer Steel Lap-welded Tubes 3 to 10 inches in diameter. 'Trans. Am. Soc. Mech. Eng.,' 1905–6, vol. 27, pp. 730–822.

Over 500 tests carried out on lap-welded steel tubes. It was found that the length of tube between transverse joints tending to hold it to circular form has practically no influence on collapsing pressure so long as length not less than about six diameters.

The formula

$$p = 1{,}000\left(1-\sqrt{1-1{,}600\frac{t^2}{d^2}}\right)$$

for values of p less than 581 lb. and values of $\frac{t}{d}$ less than ·023, and $p = 86{,}670\frac{t}{d} - 1{,}386$ for values of p and $\frac{t}{d}$ greater than the above, are given. It is also pointed out that the formula

$$p = 50{,}210{,}000\left(\frac{t}{d}\right)^3$$

represents very nearly the results of the tests on tubes in which $\frac{t}{d}$ is less than ·023. A series of curves is also given, showing the inapplicability of the older formulæ of Fairbairn, Nystrom, Grashof, Unwin, Belpaire, Wehage, Clark, &c., to modern tubes.

20 Stewart, R. T. 1907 Collapsing Pressures of Lap-welded Steel Tubes. 'Trans. Amer. Soc. Mech. Eng.,' 1907, vol. 29, pp. 123–130.

The effects of the distortion due to successive re-tests on the collapsing pressures of 10-inch lap-welded steel tubes. The following formula is given:

$$p_2 = 0{\cdot}0926\frac{p_1 - 47{\cdot}55}{(M - 0{\cdot}874)^{1{\cdot}25}} + 47{\cdot}55$$

where p_1 = collapsing pressure of normally round tube,
p_2 = that of distorted tube,
M = ratio of max. to min. diameter.

21 Stewart, R. T. 1911 Stresses in Tubes. 'Trans. Am. Soc. Mech. Eng.,' 1911, vol. 33, pp. 305–312.

An investigation showing that the stresses in the wall of a tube exposed to an external fluid-pressure are of the same character as those in a column having fixed ends.

22 Unwin, W. C. 1875 Resistance of Flues to Collapse. 'Proc. Inst. Civ. Eng.,' vol. 46, p. 225, 1875.

Showed, from shape of collapsed tube, that when length exceeded a certain value, strength would become constant. Deduced the formula

$$p = \frac{E}{6}\cdot\frac{n^2 t^3}{d^3}$$

from analogy to struts.

Where n = No. of arcs into which tube divides in collapsing.
E = Young's Modulus.

By comparison with Fairbairn's experiments, proposed the formula

$$p = 115{,}000{,}000 \frac{t^3}{l^{\cdot 9}\,d^{1\cdot 16}}$$

provided that l is less than $6{\cdot}7\, d^{t}$

$$\text{and greater than } 4{,}469\ \frac{t^{2\cdot 22}}{d^{0\cdot 18}}$$

23 Westphal, M. 1909 Tubes under External Fluid Pressure. 'Zeitschr. Vereines D. Ing.,' 53, pp. 1188–1191, 1909. 'Sci. Abs.,' 1909, No. 664.

24 Wilson, R., and others. 1876 'Engineering,' vol. 21, 1876, pp. 392, 410, 441, 458, 483, 512; vol. 22, pp. 9, 30, 36, 75.
A discussion of Fairbairn's formula.

25 Board of Trade Rules for Survey of Passenger Steamships, 1913. § 149, 'Circular Furnaces.'

26 Lloyd's Rules for Survey and Construction of Engines and Boilers of Steam Vessels. Section 16, 'Circular Furnaces.'

The Lake Villages in the Neighbourhood of Glastonbury.—Report of the Committee, consisting of Dr. R. MUNRO (*Chairman*), Professor W. BOYD DAWKINS (*Secretary*), Professor W. RIDGEWAY, Sir ARTHUR J. EVANS, Sir C. HERCULES READ, Mr. H. BALFOUR, *and* Mr. A. BULLEID, *appointed to investigate the Lake Villages in the Neighbourhood of Glastonbury in connection with a Committee of the Somersetshire Archæological and Natural History Society.* (*Drawn up by* Mr. ARTHUR BULLEID *and* Mr. H. ST. GEORGE GRAY, *the Directors of the Excavations.*)

THE fourth season's exploration of the Meare Lake Village by the Somersetshire Archæological and Natural History Society began on May 15, 1913, and was continued until June 7. The ground excavated was situated in the same field and was continuous with the work of 1910 and 1912. The digging included the examination of Mounds III. and IV., the S. quarter of Mound V., the N.E. part of Mound XIII. (remaining from last year's exploration), and portions of Mounds XV., XVII., and XVIII.

Structurally the excavations proved to be of considerable interest and the number and importance of the relics discovered this season were greater than those of the previous year.

With reference to the construction of the mounds the attention of the directors was centred in the examination of Mound XIII., which revealed many features of exceptional interest. This mound consisted of four clay floors having a total thickness of 6 ft. 8 in. The lowermost floor was subdivided into a number of thin layers of clay of various colours, each having a baked clay or stoned hearth in the

centre. In all there were fourteen superimposed hearths. The hearths belonging to Floors i., ii., and iii. were not superimposed, and were situated several feet to the N.E. of those belonging to Floor iv.

The substructure underlying the clay was of an average depth of two feet in thickness, consisting of timber and brushwood, amongst which were several well-preserved wattled hurdles, pieces of worked wood, mortised beams, and squared planks of oak. The largest plank of split oak measured 18 in. in width. Near the N.W. margin of Hearths xi. and xii., belonging to Floor iv., two superimposed planks of oak of nearly similar shape and size were discovered, separated by a layer of clay 2 in. in thickness. Each plank was perforated with three circular holes arranged in line, the holes of the upper plank being placed immediately over the corresponding perforations of the lower. Each pair of holes was filled by a pile driven vertically into the substructure below. The corresponding edge in both planks was cut semicircularly, resembling somewhat the arms of a settle.

Among other points of interest may be mentioned the central post of the dwelling erected over Floor iv., which was situated near the E. margin of the hearths, and a large area of lias stone discovered near the N. margin of the mound having the appearance of a landing-place. Near the S.W. margin of the lias stone was a silty layer of clay containing water-worn pebbles, grit, and a number of flint flakes. This layer was at the level of Floor iv.

The structural details of Dwelling-mounds III. and IV. were of less importance. The substructure, however, was noteworthy on account of the absence of timber. Besides a little brushwood the foundation had been increased by a layer of cut peat placed on the surface of the bog. It was noticed that the substructure under the N.E. half of Mound XIII. had been covered with a thick layer of peat, amongst which were patches of compressed bracken and rush.

Small portions of Mounds XV., XVII., and XVIII., adjoining Mound XIII., were examined, but a description of the structural details discovered is reserved, and will be incorporated in a future report when these dwellings have been fully explored.

The following is a summary of the objects found this year:—

Bone.—Two socketed tools with rivet-holes; a needle; an awl; two tibiæ of horse, sawn and perforated; pieces of cut rib-bone, one having two perforations; parts of four worked scapulæ (similar to several others previously found); several perforated tarsal bones of sheep or goat (? bobbins). Fifteen tarsal and carpal bones of sheep, not worked, were found laid out in rows in Mound XIII. in black earth belonging to Floor iv.—evidently a collection made for the purpose of converting them into tools.

Antler.—Eight weaving-combs, some incomplete, some ornamented; two 'cheek-pieces' for horse harness; roe-deer antler knife-handle; several cut pieces of red and roe deer antler.

Beads.—Finely preserved amber bead (the second found at Meare); two glass beads (one with spirals); and a baked clay bead.

Bronze.—Pair of tweezers; two finger-rings; flat ring; rivets; and a few fragmentary objects. Also a solid bronze figure, perhaps

intended to represent a boar with long ears—unfortunately the facial portion has been broken, but it is seen that there was a perforation through the forehead. Along the back there is a groove in which a thin bronze crest was inserted, traces of which remain. In length the figure is about 2½ in.; height over fore-legs about 1⅛ in. It is similar in character to the series of bronze figures—three boars and two nondescript animals—found at Hounslow,[1] and another boar found at Guilden Morden, Cambs.

Crucibles.—Two fragments.

Lead and Tin.—Two lumps of lead ore, and a flat, wide ring, perhaps containing a large percentage of tin.

Iron.—The iron objects for the greater part are much corroded and included a fragmentary ring encased in thin bronze, part of a file, a punch or narrow chisel, and a large pointed bar, of square section, which may have been an earth-anvil.

Kimmeridge Shale.—An earring; part of a vessel, or cup; a knife-cut armlet (split); and parts of lathe-turned armlets.

Pottery.—Mound XIII. produced a large amount of pottery, the thicker and ruder wares being found chiefly in the substructure. The proportion of ornamented pottery was again large, but there is a great amount of restoration work to do before the designs can be fully described. One ornamented bowl was revealed in six pieces, which, when joined, will make the vessel practically complete. The greater part of a plain pot was discovered on the fourth floor of Mound XIII. Ornamented bases of pots were also found this season.

Flint.—Chipped and polished celt, of Neolithic type, length 4½ in. (the second stone axe from Meare); an arrowhead and part of another; a hammerstone; a dozen scrapers; two cores; and a large number of flakes, some of which were burnt. Of the flint flakes, 154 were collected from Mound XIII. and 16 from Mound III.

Sling-stones.—Two hundred and seventeen were collected this season, including 89 from Mound III. and 75 from Mound XIII. Thirteen baked clay sling-bullets and four unbaked ones were also found. Ninety-one whetstones were collected, including 57 from Mound XIII.

Querns.—Several quern fragments were found, but only one complete saddle quern.

Spindle-whorls.—Seven specimens, all of stone, were found this year in various stages of manufacture.

Human Remains.—Humerus found in the fourth floor of Mound XIII.

Animal Remains.—Plentiful, including several bird-bones. In the foundation of Mound XIII. a skeleton of roach (*Leuciscus rutilus*) was uncovered.

[1] *Proc. Soc. Antiq.*, 2nd ser., iii., 90; *Early Iron Age Guide, Brit. Mus.*, 1905, p. 135.

The Age of Stone Circles.—Report of the Committee, consisting of Sir C. HERCULES READ *(Chairman)*, Mr. H. BALFOUR *(Secretary)*, Dr. G. A. AUDEN, Professor W. RIDGEWAY, Dr. J. G. GARSON, Sir A. J. EVANS, Dr. R. MUNRO, Professor BOYD DAWKINS, *and* Mr. A. L. LEWIS, *appointed to conduct Explorations with the object of ascertaining the Age of Stone Circles. (Drawn up by the Secretary.)*

OWING to the smallness of the balance in hand, which only amounted to two guineas, it has not been possible to carry out any work at Avebury during the present year. It was hoped that this sum might be available for re-levelling the inequalities in the ground caused by shrinkage of soil disturbed during previous excavations; but as the levelling will have to be done under skilled supervision, the small amount would only suffice if a responsible person were on the spot, and as there was no grant for excavation work there was no suitable expert available. As soon as excavation work can be resumed at Avebury the levelling and repairs can be conducted concurrently with the more important operations and at trifling expense. In view of the scientific results already obtained from the excavations in former years, and as a means of adding to their value in determining the period to which the Avebury stone circle should be assigned, it is most important that fresh explorations should be made in another portion of the earthwork. It is especially desirable that a portion of the fosse to the east of the causeway leading from Kennet Avenue should be excavated down to its original bottom. This is on the opposite side of the causeway to the site of the previous excavations. This important piece of work should either confirm or correct the impressions derived from the sections cut through the fosse on former occasions, and may be expected to lead to definite results provided that a sufficiently large area can be explored. With this object in view, the Committee apply for re-election and for a grant of 50*l.*, together with the small balance in hand, which would still be allotted to the repairing of damage caused by previous excavations. The Committee also wish to apply for leave to invite subscriptions from other sources, in order to acquire a sum sufficient for moderately extensive investigation. Owing to the great depth of the silting in the fosse, the cost of excavation is relatively high, and the grant applied for would by itself only be sufficient for a very limited exploration of the fosse; but if the grant is allotted, a further sum will be available from private sources, enabling the work to be conducted on a more substantial scale, with every prospect of valuable results. It is important that excavations should be renewed at Avebury next spring if possible, and not be delayed for another year, as there would be a better chance of enlisting the services of labourers who have already been employed in this work and have learned something of the requirements.

The Committee desire to express their deep regret at the death of Lord Avebury, who had not only served upon the Committee for several years, but had also freely given permission for excavations

to be made in those portions of Avebury stone circle and earthworks which were his own property. He was deeply interested in the work, and was anxious that it should be carried out in a thorough manner, so as to yield results which might solve finally the problem of the age of this splendid monument.

The Production of Certified Copies of Hausa Manuscripts.—Report of the Committee, consisting of Mr. E. S. HARTLAND *(Chairman)*, Professor J. L. MYRES *(Secretary)*, Mr. W. CROOKE, *and* Major A. J. N. TREMEARNE.

AFTER careful consideration of the question in all its bearings the Committee decided to accept the proposal of Messrs. Bale, Sons, & Danielsson, Limited, to print the Hausa manuscript tales, collected by Major Tremearne, as a companion volume to that already in preparation for him, and to provide twenty copies for the purposes of the Committee, in consideration of a grant of 20*l.* towards the expense of printing. Major Tremearne has undertaken to certify the accuracy of these twenty copies, after comparison with his manuscript, and to adopt an approved system of transliteration in preparing the tales for the press. The printing is already in hand, and the volume of tales should be ready for publication early in the autumn of 1913.

Artificial Islands in the Lochs of the Highlands of Scotland.—Third Report of the Committee, consisting of Dr. R. MUNRO *(Chairman)*, Mr. A. J. B. WACE *(Secretary)*, *and* Professors W. BOYD DAWKINS, J. L. MYRES, *and* W. RIDGEWAY, *on the distribution thereof.*

THE Committee have received the following report from Dom Odo Blundell, of Fort Augustus, in continuation of the two previous reports of the Committee. Much fresh information has been collected, and a grant has been made by the Carnegie Trust to Dr. Munro for the excavation of the island in Loch Kinellan, which it is hoped to undertake at the first opportunity. In view of the proposed excavation, the Committee ask to be reappointed with the balance of last year's grant and a fresh grant of 10*l.*

APPENDIX.

Report from DOM ODO BLUNDELL, *O.S.B.*

Since the report of last year several islands have been visited, and an application has been made for means to excavate the island in Loch Kinellan. By request of the shooting tenant, no work was to be done in this island till after the end of June, so that up to the date of writing it has not been possible to investigate this example further.

Loch Tay.—Mr. Hugh Mitchell has continued his examination of the examples in this loch, which he thus summarises in a recent letter:

'The artificial islands in Loch Tay, so far as I can ascertain, are as follows:—

'1. The Priory Island, or "Y," of Loch Tay.

'2. Cuigeal Mairi, or Mary's Distaff, about 200 yards west from the Priory Island, which is submerged when the loch is at its normal height, but it is marked with a pole.

'3. Island in Fernan Bay, which can be seen at low water, and which is marked by a pole to prevent the steamer or boats striking it.

'4. Eilean nan Brebean, which is quite complete, is in the bay east of Morenish. It is almost wholly formed of stones of from 10 lb. to 40 lb. in weight.

'5. In Finlarig Bay, to the west of Killin Pier. This island is marked by a tree.

'6. There is also a small island in good preservation on the west side of Acharn Bay. It has no name.'

Loch Achnacloich.—At the invitation of Major Cuthbert, Factor for Mr. Perrins, of Ardross Castle, I visited this loch on February 25. Major Cuthbert was absent for the day, but his senior clerk, Mr. Macdonald, motored me to the loch, about two miles distant. We easily found the cairn at the east end of the loch and about 80 yards distant from the shore. The top was covered by a few inches of water, but we could see that it exactly resembled the islands in Loch Moy and Loch Garry, which have been fully described elsewhere during the present survey. At the outer edge of the rubble building the depth of the water was from 8 to 10 feet, and the diameter of what may be judged to have been the top of the island is about 50 feet. With the boat-hook we could feel the wood that formed the foundation of the island, and could bring up chips from the logs, but did not succeed in dislodging one of these. The chips of wood showed that the logs were of oak.

Loch Lomond.—Mr. Walter Macdermott, who has forty years' experience of fishing on the loch, of which he knows every bay and inlet, stated that there is a large cairn of stones in the loch just south of Doune and another opposite Rowchoish—the one investigated by Mr. Robertson, Inversnaid. The Mill Cairn, in Ross Bay, he is sure is artificial. On the west side of the loch Mr. Macdermott mentions a large cairn in Luss Bay, just north of the pier, and another between the two points of Straddan Bay, with a third just south of this last. Mr. Henry Lamont, Secretary of the Loch Lomond Fishing Association, confirms all the above suggestions, and repeated his assurance that Insh Galbraith would be found to be artificial. Mr. Macdermott suggested further examples, such as the cairn in Rossdhu Bay, and another south of this and midway between Auchintullich House and the burn. He agrees with Mr. Lynn in suggesting the cairn opposite Auchinheglish, and also the one opposite Cameron Point; while he well remembers the occasion when Dr. Robert Munro and Mr. David MacRitchie examined the island opposite Strathcashel Point. Dr. Munro, the author of several well-known works on artificial islands and the greatest living authority on the subject, informs me that it

was in 1901 that he visited this island. As the water was low at the time, they were able to stand on the woodwork of which the island is partly composed. It then measured about 15 feet by 20 feet, and is distant 25 yards from the shore.

Another resident in the Loch Lomond district, Mr. MacGregor, farmer, Garabel, reported seeing a large cairn of stones or small island at the mouth of the River Falloch on the north or Ardleish side. This he hoped to investigate more fully during the coming summer. From the above information there is every reason to hope that this loch will prove of great interest, for even if some of the islands suggested prove to be natural, the fact that one has already been certified as artificial by so competent observers as Dr. Munro and Mr. MacRitchie leads one to suspect that others will be in the same category.

Additional Note.

By Mr. Hugh Munro, *C.E., Kilmarnock.*

Description of a supposed Artificial Island in a small Loch near Loch Ranza, Arran.

The loch with the island is situated about a mile up the valley from Loch Ranza Pier and about 500 yards to the south of the public road. It lies at the base of a steep hill, and a small burn flows from the north-west end to the river. The bottom of the loch is gravelly, and it does not appear to be of great depth. The island lies towards the north shore, and is probably 40 feet long by 10 feet wide, and covered with bushes (a species of willow). In one place there was an almost continuous line of peaty matter from the island to the shore, and I reached the island by laying ladders on this peat, which was otherwise too soft to bear my weight. The island had a thick growth of grass, and felt quite solid underfoot. Deer had formed a path around it, and I learned afterwards that in dry summers children could wade to it. I had no implements for digging, and so could not examine the structure of the place, but quite close to the solid part I could push a pole six or eight feet through soft mud. There is no evidence to show that the island is artificial; my reason for supposing it to be so is that the island appeared out of place in the geological configuration of the neighbourhood of the loch.

The Organisation of Anthropometric Investigation in the British Isles.—Report of the Committee, consisting of Professor A. Thomson *(Chairman)*, Dr. F. C. Shrubsall *(Secretary)*, Dr. G. A. Auden, Dr. Duckworth, Professor A. Keith, *and* Professor G. Elliot Smith.

The Committee fully considered the lines of possible future work, and concluded that the most useful and pressing subject would be the correlation and co-ordination of the records of physique now being accumulated by the medical officers of the various education authorities. This subject would, however, require a large part of the time of anyone who

undertook to be Secretary of the Committee, if, indeed, it did not demand his undivided attention. It would be difficult to find anyone who could spare the time and energy devoted to this Committee by the late Secretary, Mr. J. Gray. The Committee have therefore reluctantly come to the conclusion that they could not undertake the task, but recommend that if any suitable investigator becomes available the Section should consider favourably the formation of a new Committee to render assistance to the project. The work of the former Anthropometric Committee of the Association has become so well known that it would materially aid any future inquiry to be conducted under the ægis of the Association.

Excavations on Roman Sites in Britain.—Report of the Committee, consisting of Professor RIDGEWAY *(Chairman)*, Professor R. C. BOSANQUET *(Secretary)*, Dr. T. ASHBY, Mr. WILLOUGHBY GARDNER, *and* Professor J. L. MYRES, *appointed to co-operate with Local Committees in Excavations on Roman Sites in Britain.*

THIS Committee was reappointed in September 1912, to co-operate with the Abergele Antiquarian Association in the exploration of the hill-fort in Parc-y-meirch Wood, Kinmel Park, Denbighshire.

In recent years several hill-forts in North Wales have been investigated: (1) Tre'r Ceiri in Carnarvonshire, where sixty-four huts were excavated in 1903 and 1906 by the Cambrian Archæological Association. (2) Pen-y-gaer, near Llanbedr-y-cenin, Carnarvonshire, examined by the Nant Conwy Antiquarian Society in 1905. (3) Pen-y-corddyn Mawr, near Llanddulas, Denbighshire, examined by the Abergele Antiquarian Association in 1905-9. (4) Braich-y-ddinas on Penmaenmawr Mountain, Carnarvonshire, where a survey, accompanied by excavation, is being made for the Cambrian Archæological Association.

Reports on (1), (2), and (4), by Mr. Harold Hughes and others, and on (2) and (3) by Mr. Willoughby Gardner, have appeared in 'Archæologia Cambrensis,'[1] and have furnished data for comparing the methods of construction used in these forts and determining the periods during which they were occupied. The fact which directly concerns this Committee is that three of them yielded Roman pottery: Tre'r Ceiri and Braich-y-ddinas, which are village-sites with numerous hut-circles, producing much more than Pen-y-corddyn, which was rather a refuge fort, bearing marks of hasty construction and demolition.

Similar evidence of occupation in Roman times was recorded in 1850 by Mr. W. Wynne Foulkes for three of the native forts which crown the heights of the Clwyd range on the borders of Flint and

[1] Sixth Series. (1) Tre'r Ceiri, iv. 1 and vii. 38. (2) Pen-y-gaer, vi. 241. (3) Pen-y-corddyn, x. 79 (4) Braich-y-ddinas, xii. 169 and xiii. 353. The work at Tre'r Ceiri was done by the Rev. S. Baring Gould and Mr. R. Burnard in 1903, by Professor Boyd Dawkins, Col. L. W. Morgan, and Mr. Harold Hughes in 1906.

Denbigh. The inference drawn at that time was that these sites had been occupied 'by the Romans.' It has become increasingly plain in recent years that 'Roman' pottery, both Continental 'Samian' and coarser home-made wares, was used by the natives throughout the province of Britain, and in some cases also outside its limits; and, as much of this pottery can be dated, it may be expected to furnish a useful index of the distribution of the native population at various stages of the Roman occupation. The excavations carried out in recent years by Mr. E. Neil Baynes at Din Lligwy, on the north-east coast of Anglesey, furnish an admirable example of the amount of information as to native culture under Roman influence which may be recovered from a fortified village-site.[2]

From this point of view, the fort of Parc-y-meirch presents a most promising field of inquiry. The excavation begun in 1912 by the Abergele Antiquarian Association was originally suggested by the Cambrian Archæological Association, through its President, Professor Boyd Dawkins, and has received generous support both from the national society and from subscribers in the district. But the exceptional size of the fortifications—the main rampart rises fifty feet vertically above the bottom of its encircling ditch—and the complexity of the stratification, due to more than one destruction and rebuilding, make it a very costly site to dig. The grant of 15*l.* allotted to this Committee has been spent in wages, supplementing the funds raised from other sources, and has made possible a more extended examination of the ditches and gates. The work has been superintended by Mr. Willoughby Gardner, whose account of this season's work is printed as an appendix to this report. A full record has been made in the form of plans, sections, and photographs. Professor Arthur Keith has kindly undertaken to describe the human remains found at more than one point in the rock-cut ditch.

The Committee asks to be reappointed and applies for a renewal of its grant.

APPENDIX TO COMMITTEE'S REPORT.

Further Excavations in the Ancient Hill Fort in Parc-y-meirch Wood, Kinmel Park, Abegele, North Wales, during 1913. By WILLOUGHBY GARDNER, *F.L.S.*

At the Dundee Meeting last September an account was given of some excavations made, by kind permission of the owner, Colonel Hughes, in this native hill fort by the Abergele Antiquarian Society and the Cambrian Archæological Association, as printed in abstract in the 'Report of the British Association,' 1912, pages 611-12. This year further work has been done by the same societies during six weeks upon this extensive site, by help of ten labourers and several amateur assistants, and aided by Colonel Hughes in very many material ways. Indeed, exploration of this wooded hill would have been impossible had not Colonel Hughes most generously allowed trees to be cut down whenever necessary and himself lent tackle for the work. This

[2] *Arch. Camb.*, VI., viii. 183.

season's excavation work has been much stimulated by the invaluable co-operation of one of the Research Committees of Section H of the British Association, as well as helped by a grant of 15*l.* from the same source. Professor R. C. Bosanquet, the Secretary of this Committee, spent five days with us upon the site.

Attention was first directed to the interior area at the north end, and to the artificial defences and an entrance near that end; subsequently the defences to the south and south-east were investigated, and finally further examination was made of the south-east entrance. Last year evidence was obtained of three occupations of the hill fort in a section of three superincumbent roadways in this entrance. It was shown by relics unearthed upon the topmost roadway that the latest of these occupations was during the fourth century A.D. Many similar relics (of which photographs were exhibited) were found also in the interior area of the stronghold, proving that portions of the hilltop at any rate were inhabited by a primitive-living native resident population at that time.

During the present summer excavations have revealed relics, in the form of pottery, coins, &c., belonging to the same period at the northern end of the hill fort and elsewhere. It was thought at first that the fourth-century occupation of the hill-top might have been partial only, but identical remains have now been found within the stronghold at the south-east, the south, the south-west, and the north, proving an occupation of practically the entire site by a large number of people, who, besides possessing implements and utensils of home manufacture, used Roman pottery and a Roman currency. All these fourth-century relics were found very near to the present surface, being covered by one to one and a half feet only of vegetable humus.

Last year a plan showed the fourth-century roadway in the south-east entrance as far as excavated. It was a passage with roughly built side walls in dry masonry, thirty-eight feet long, cut through wide-spreading ruins; it has since been found that it was closed by four gates set up at intervals within its course, of which the holes for the wooden gate-posts, and some charred wood fragments found in a few of them alone survive. Photographs exhibited showed that portions of the side walls of this passage were built upon previous ruins. Further excavations this season have revealed two guardhouses here, one on each side within the entrance; these also are constructed amid ruins, their sites being dug out of the fallen *débris* of earlier guardhouses.

Work during 1912 showed that the inner ditch at the south side of the stronghold was filled with the ruin of a wall which previously stood on the rampart above. This year's investigations have shown that apparently the whole length of this ditch was so filled as well as a similar one at the north end. Cuttings were made across the second ditch on the south-east, south, and south-west sides, and it also was found to be more or less filled with stony *débris* in the neighbourhood of the entrance and on the south-west side. It was further discovered this year that sometimes the first and sometimes the second of these

ditches had been in part re-excavated at a later date. This was apparently the work of the fourth-century inhabitants of the stronghold.

The accumulated results of the two seasons' work now show that during the fourth century, or earlier, the natives of the district reoccupied the hill fort after its previous destruction at some unknown time; that they entrenched themselves behind ramparts roughly constructed upon ruins and defended by shallow ditches re-excavated in deeper ones previously filled up; and that they cut a fresh entrance to the south-east through the *débris* of an older one.

A closer date for this return to the hill-top is apparently obtained by further finds, made this year, of Roman 'third' and 'small brass' coins. The total number found during the two seasons amounts to thirty-seven from sixteen different sites; they are as follows:—One Trajan, very worn; one Julia Mamaea, worn; four Gallienus, more or less worn; one Claudius Gothicus, fair condition; three Tetricus, cut and worn; two Carausius, in good condition; one Crispus, corroded; four Constantinus Magnus (minted about A.D. 335), in fine condition; one Constantinus II., in fine condition; one Constantius II., in good condition; ten Constans, in corroded to fine condition; three Magnentius, in corroded to good condition; one Valens, in good condition; one Gratianus, in good condition; one illegible. It is to be noted that though careful watch was kept for the 'minimi' of the fifth century, none were discovered. Most of the coins found were struck in Gaul; the majority were minted A.D. 335 to A.D. 353, and the latest about A.D. 380. On the numismatic evidence therefore this would seem to point to a reoccupation of the site somewhere about A.D. 340, and either to a final abandonment, or else to a cutting off of traffic with the Roman world, soon after A.D. 380. It is suggested that the return of the natives to the ruined fort on the hill-top may have been caused by raids of Irish or other sea pirates who boldly infested the coast after the withdrawal of the Roman troops from this district some time prior to A.D. 340.

But, as has been previously pointed out, the above is a mere episode in the story of this hill fort, which is of far earlier origin. This summer's excavations have thrown further light upon its earlier constructions. The plan of the more ancient entrance at the south-east, also found to have two guardhouses, has been in part recovered from the ruins. This entrance had a good gravelled roadway and side walls in dry masonry better built than those of the later superincumbent entrance; it had apparently post-holes for a single gate only. In many ways it resembles one of the three entrances excavated by the Abergele Antiquarian Association some years ago in the ancient hill-fortress on Pen-y-corddyn, three miles distant.

Eighteen cuttings made at various points in front of the ramparts have revealed the courses of ditches for the most part previously hidden from sight by *débris*. At the north end there was a single ditch across the spur of the hill below the main rampart, and this ditch was continued along the north-east side. It was V-shaped, and was cut, from five to seven feet deep, and from seven to nine feet wide across its top, out of solid rock. Opposite to a point where an entrance had

been previously located at the north-east of the hill fort, this ditch was found to curve slightly inwards, shallowing to less than two feet; a similar ditch further on was found to curve slightly outwards, without shallowing, so as to form an overlap on either side of the rock causeway which leads up to the entrance. This ditch was found to be filled to the brim with limestone rubble and wall facing stones from the ramparts above. That these stones had not fallen merely from the natural decay of the wall, but rather that the ramparts had been deliberately thrown down into the ditch, was shown by the rubble being frequently clean and free from soil throughout. And that this throwing down took place not long after the ditch was cut was made plain by the fact of there being practically no silting upon the solid rock below the stones. At the south side of the hill-fort this year's excavations showed three more or less parallel ditches across the level neck of land below the great main rampart; the inner one was V-shaped and the others nearly so. The dimensions of the inner one approximated to that of the ditch at the north end, but the outer ones were generally wider and sometimes deeper. Here also the inner ditch was found to be filled with the ruins of a dry masonry wall which formerly existed upon the top of the main rampart. The stones and rubble showed similar features to those described at the north end, again proving that the wall had not merely fallen from decay, but had been deliberately thrown down into the ditch not long after the latter was cut. At the south-east side only two parallel ditches were found on excavation, the first entirely, and the second at the end near the entrance, being filled with *débris* in a similar way.

The ramparts also showed marks of destruction in many places. All along the main south rampart the whole of the wall just mentioned was thrown down the slope with the exception of a few foundation stones here and there. To the south-west not only the wall at the top, but the entire rampart, had been deliberately destroyed—shovelled down the slopes into the ditches below. At the north end the facing wall of the rampart had been removed to its foundation stones. At well-nigh every point where investigations have hitherto been made—in the south-east entrance, in the ramparts, in the ditches to the north, the north-east, the south-east, the south, and the south-west—destruction is everywhere apparent; and, further, there are traces of a great conflagration at some early period in the large quantities of burned limestone found in several places, *e.g.*, below the floors and walls of the guard-chambers in the south-east entrance. A few human remains and some fragments of Roman pottery have been found deep in the ditches and upon the second road in the south-east entrance; but relics hitherto unearthed in definite strata of the ruins of the earlier fortifications are disappointingly few, and do not include anything that has yet been accurately dated.

Up to the present, therefore, no certain evidence of the time of this destruction of the hill fort is forthcoming, except that it was during an early period of its existence. But it is difficult to conceive of its having been the result either of local tribal warfare or of piratical raids, and it is suggested that it shows the work of the Roman armies,

perhaps during one of their expeditions into the district in the first century A.D.

The section of the three roadways in the south-east entrance, of which a photograph was shown last year, pointed to three occupations of the hill fort—the fourth century one and two of earlier date. This year's investigations afford similar evidence from other directions, but it is not yet possible to apportion the superincumbent roadways found to the various constructions and destructions of entrances, of ramparts, and of ditches that have since been unearthed; in particular, a massive wall which suggests a still earlier entrance than that containing the three superincumbent roadways has been brought to light, eighteen feet to the east of the latter. It is hoped that this apportionment may be accomplished by future excavations.

Although this year's work has advanced our knowledge of this extensive site by several steps, the explorers feel that they are only on the threshold of an investigation which promises much information about a dark period in the early history of Wales.

Prehistoric Site at Bishop's Stortford.—Report of the Committee, consisting of Professor W. RIDGEWAY (*Chairman*), Dr. W. L. H. DUCKWORTH (*Secretary*), Professor W. BOYD DAWKINS, Dr. A. C. HADDON, *and* Dr. W. H. MARETT TIMS, *appointed to co-operate with a Local Committee in the excavation thereon.*

ON Wednesday, May 7, Dr. Haddon and the Secretary visited Bishop's Stortford at the invitation of the Rev. Dr. Irving, B.A., and with him they made an inspection of the site on which the 'fossil horse' was found about three and a half years ago.

The site is at the western side of a meadow about half a mile west of the town and at a considerable height above the Stort valley. The actual excavation in which the skeleton was found is now a lily-pond. A wire fence separates the meadow from the property occupied by Dr. Dockray. A small trial trench in the meadow below the pond was found to be filled with water. On the actual site there is at present no exposure, trench, or section of any kind, further than that furnished by the lily-pond itself, so that Dr. Haddon and the Secretary can give only a bare statement of its position as described to them, and for details must refer to reports already published. It would appear that Dr. Dockray may possibly become interested in the meadow adjoining his land, and in that event he may carry out extensive levelling or scarping. Should this surmise be realised, the interest of the skeleton already found calls for the maintenance of as close an inspection as possible.

While regretting that there is little to report to the Committee in connection with the special object with which it was originally appointed, beyond what was reported by Dr. Irving in 1911 at the Portsmouth Meeting, Dr. Haddon and the Secretary desire to express

their appreciation of Dr. Irving's efforts to elucidate the difficult local problems in geology and archæology, and to record their satisfaction with the valuable work he has accomplished and continues to carry out in keeping definite records of local discoveries. Dr. Irving's publications will show the nature and scope of his activities, but in this Report it is advisable to mention that he gave a general demonstration (of the local geological conditions) to Dr. Haddon and the Secretary. In particular the gravel pit known as Frere's pit was visited, and after the main exposure had been viewed, attention was directed to a trench in the Boulder-clay (above the gravel) in which prehistoric sherds and other objects were found in 1912 by Dr. Irving and his sons. A visit was paid subsequently to Gilbey's gravel pit, and the remarkable fact was demonstrated that the Boulder-clay so conspicuous in Frere's pit is absent from Gilbey's, though the two are at most some two hundred yards apart, a 'river-drift' deposit occupying the horizon of the Boulder-clay. Dr. Haddon and the Secretary were thus enabled to gain a good idea of two typical exposures of the locality.

In terminating this report Dr. Haddon and the Secretary have to express their opinion that under the present circumstances it does not appear to them necessary that the special committee to investigate the prehistoric site at Bishop's Stortford should be reappointed.

Palæolithic Sites in the West of England.—Report of the Committee, consisting of Professor W. BOYD DAWKINS *(Chairman)*, Dr. W. L. H. DUCKWORTH *(Secretary), and* Professor A. KEITH, *appointed to report thereon.*

THE members of the Committee visited various caves in the West of England during the early part of the present year (1913).

Inasmuch as they have not been able to meet for the purpose of combining the results of their observations, the members of the Committee ask to be reappointed without a grant.

Anæsthetics.—Fifth Interim Report of the Committee, consisting of Dr. A. D. WALLER *(Chairman)*, Sir FREDERIC HEWITT *(Secretary)*, Dr. BLUMFELD, Mr. J. A. GARDNER, *and* Dr. G. A. BUCKMASTER, *appointed to acquire further knowledge, Clinical and Experimental, concerning Anæsthetics—especially Chloroform, Ether, and Alcohol—with special reference to Deaths by or during Anæsthesia, and their possible diminution.*

DURING the past year we have acquired further experience of the use of the chloroform-balance in the hospital and in the laboratory. Our opinion has been confirmed that this apparatus affords the safest possible and the most convenient fixed means of inducing and maintaining

anæsthesia upon man and animals. As a laboratory fixture, so far from requiring a greater expenditure of time and attention, its routine use has proved to be economical in both these respects; the smaller animals, such as dogs, cats, rabbits, and mice, are most conveniently prepared and kept ready for operation in a bell-jar or other confined space by means of a continuous stream of chloroform and air at percentages rising from 0 to 2 per cent., and subsequently falling from 1 to 0.5 per cent.

Our attention has been directed to the action of local anæsthetics—cocaine, stovaine, 'novocaine,' 'eucaine,' &c., and we have undertaken observations of their relative toxicities as measured by their effects upon isolated tissues. But upon the present occasion we desire to lay particular stress upon the practical dangers involved in the use of these powerful poisons by unqualified persons, more especially in connection with cheap dentistry.

This matter has been closely investigated by our Honorary Secretary, Sir Frederic Hewitt, and we consider that the facts brought to light in that investigation are of such gravity as to require the most serious consideration of the British Association. The detailed report of Sir F. Hewitt and a formal resolution arising out of that report have been discussed at length in Section I, and the unanimous opinion of the Section, after listening to the opinions expressed by several independent authorities—Professor Barling, Dr. Saundby, Dr. McCardie, Dr. George Foy, Mr. Vernon Harcourt, Mr. Leonard Hill, Mr. Joscelyne, and Mr. Pearce—is to the effect that it is desirable at this juncture that the Committee of Section I should consider, and if judged proper forward to the Council of the Association, the following resolution:—

'That in view of the fact that numerous deaths continue to take place from anæsthetics administered by unregistered persons, the Committee of the Section of Physiology of the British Association appeals to the Council of the Association to represent to the Home Office and to the Privy Council the urgent need of legislation.'

The Committee asks to be reappointed, and that its original reference should be extended to include the study of 'local anæsthetics, such as cocaine and stovaine.'

APPENDIX.

An Account of Three Fatal Cases of Poisoning by Cocaine administered by Unqualified Persons. By Sir Frederic Hewitt.

As Honorary Secretary of the Committee, and as one of those who have for some time past urged the need of legislation to prohibit the administration of anæsthetics by unqualified persons, I venture to draw the attention of the Committee to three coroners' inquests which have taken place within the past few months upon members of the working-classes to whom cocaine or some derivative thereof has been administered for tooth-extraction by unregistered dentists.

The evidence given at the first of the three inquests went to show that the deceased was a woman forty-five years of age, the wife of a

labourer earning 16s. a week. She consulted a wholly unqualified and unregistered 'practitioner of dentistry,' agreeing to pay him four guineas for preliminary tooth extraction and subsequent artificial teeth. The 'practitioner of dentistry' admitted that whilst the law permitted him to use this title he could not call himself a 'dental practitioner.' Before the extraction he injected a solution of cocaine and adrenalin, disregarding the fact that the gums were very unhealthy. He also ignored the warning on the label of the bottle containing the analgesic solution: 'The contents of this package are only to be used in accordance with the prescription of a medical practitioner.' Some hours after the operation the patient became semi-delirious and retched. Next morning she became unconscious and convulsed. She died early on the following morning. The 'practitioner of dentistry' stated in evidence that he had only injected ⅓ gr. cocaine. At the post-mortem the gums were found to be lacerated and the heart and kidneys to be diseased, but the cause of death, in the opinion of the two medical men called in, was cocaine poisoning. The jury returned a verdict of death by misadventure, but 'asked the coroner to severely censure Mr. —— for administering such large quantities of cocaine without having the necessary qualification.'

At the second inquest the evidence showed that the patient had been a perfectly healthy woman, aged twenty-nine, the wife of a bricklayer. Suffering from toothache she consulted a so-called 'dental operator,' who injected cocaine and then extracted a decayed tooth. There was considerable inflammation around the tooth—a state which is now generally regarded as strongly contra-indicating injection. The patient on her return home lay 'in a dizzy condition.' A week after the operation a medical man was called in who found the patient to be 'suffering from some narcotic poison.' She was in a 'collapsed condition.' Next day the narcotic symptoms passed off and the mouth was found to be septic. The patient died four days later. At the post-mortem a condition of pyæmia was found originating in disease of the jaw around the tooth socket. In his remarks to the jury the coroner said 'he thought the position was certainly a very unsatisfactory one that people without any qualification of having been apprenticed—in what he might call a legal way—to a dentist should be allowed to operate by injecting cocaine or any derivative of cocaine, or any other drug of that kind.' Owing, no doubt, to the fact that the 'dental operator' exercised his right to answer no incriminating questions, the hands of the jury were to a great extent tied, and after much difficulty they returned a verdict 'that the deceased died from blood-poisoning, but that there was not sufficient evidence to show how it was produced.' Fortunately, further light was thrown upon this lamentable case some two months after the inquest, when the husband of the deceased woman sued the so-called 'dental operator' for damages in respect of his wife's death and obtained judgment for 70*l*. At the civil proceedings it was shown that the defendant 'advertised painless extractions with no after-effects.' The prosecution stated that 'the negligence complained of was that the defendant wrongly injected a solution of cocaine into an abscess which

he ought to have known to exist, thereby causing blood-poisoning and death.' In the course of the proceedings the defendant admitted that on one occasion he had paid 2*l.* compensation to a patient upon whom he had performed an injection, and that in two other cases he had been obliged to pay for medical advice required by patients after his operations. The judge found that the deceased 'was negligently treated by the defendant—ignorantly of course, but negligently. This negligence was the cause of the illness with which she was seized, and that illness caused her death.'

The third inquest was held upon the body of a young married woman twenty-three years of age, whose occupation had been that of shirt-making. Though quite able to do her work her general health had not been very good. She had suffered from toothache. The evidence showed that she had obtained the services of a 'dental operating mechanic,' who, having come to the house, injected cocaine as a preliminary to tooth extraction. Very shortly after the injection the patient complained of curious sensations in her hands and feet, and rapidly became unconscious. 'Her lips, face and hands were blue, and she was breathing heavily.' She died very shortly afterwards. The post-mortem examination showed that the deceased was 'well-nourished and sound.' In summing up the coroner said 'he thought that, in view of the fact that there was so much of this injecting going on by unqualified persons, the sooner something was done to prevent it the better it would be for the public.' The jury returned a 'verdict that death was due to misadventure, but added a recommendation that the law should be so amended as to prohibit the use of anæsthetics except by fully qualified practitioners.' The coroner said 'he cordially agreed with the recommendation and would communicate it to the Home Office.'

There have been several similar inquests in recent years. At one of these, held in Ireland, upon a young woman of nineteen, to whom cocaine had been administered, but whose death was more probably due to hæmorrhage, the jury strongly condemned the action of unqualified persons going about the country performing dental operations. The unqualified dentist was committed for manslaughter, and, in summing up at the trial the judge said: 'So far as the citizens were concerned he thought it was a highly dangerous thing that these young men should be let out to try their apprentice hand—for it was nothing else—upon patients.' The prisoner was found guilty, but recommended to mercy on the grounds of his ignorance, the judge considering the dental firm, whose employé the prisoner was, more culpable.

It is highly important, in this connection, to bear in mind the following facts with regard to cocaine and its derivatives: (1) The risk attendant upon the injection of cocaine and similar analgesics is quite as great from the septic as from the purely toxic side. It hence happens that apart from the numerous cases of cocaine poisoning which occur, a few of which terminate in inquests, there are a large number of others which escape attention, the victims either suffering from prolonged impairment of health or dying from sequelæ rarely traced to

their true causes. (2) The injection of cocaine or its derivatives may lead to dangerous or fatal symptoms by (*a*) direct toxicity; (*b*) the introduction of septic organisms into the circulation through improper sterilisation of injecting appliances; (*c*) lacerating and reducing the vitality and power of recovery of inflamed tissues into which the analgesic solution may have been forced, with the result that sloughing or necrosis follows; and (*d*) 'the injected fluid, not only driving out the blood and lymph, but also dispersing pathogenic organisms into the tissues and even into the general circulation' (Gibbs). (3) It is hence clear that without proper medical or dental education and training the risks to the public of such injections are very great.

Electromotive Phenomena in Plants.—Report of the Committee, consisting of Dr. A. D. Waller (*Chairman*), Mrs. Waller (*Secretary*), Professors J. B. Farmer *and* Veley, *and* Dr. F. O'B. Ellison. (*Drawn up by the Chairman.*)

In previous reports we have stated that the presence of a 'blaze-current' is a sign that a given vegetable tissue is alive and also *how much* it is alive, *i.e.*, that it is a quantitative as well as a qualitative test of the living state.

In a recent number of the 'Annals of Botany'[1] W. Laurence Balls, after a laborious attempt to estimate the vitality of cotton plants by means of this test, comes to the conclusion that the method, although holding good as a 'death-test,' does not seem to be a 'vitality-test' in a quantitative sense, and that it failed of its object with regard to the testing of root samples, because the small roots give the most insignificant results.

Mr. Balls has very courageously attacked a new and difficult problem with very inadequate resources, *i.e.*, with a galvanometer of 22 ohms resistance, with induction currents of excessive strength, and with a circuit of such intricacy as to make it difficult to verify direction of excitation and response, and impossible to obtain systematic data. I think it is very much to Mr. Balls's credit, and incidentally a very encouraging sign of the applicability of the blaze-test, that it should have been possible to obtain any result whatever under such conditions. And I venture to forecast that the tenacity of purpose that has enabled Mr. Balls to discover by his apparatus that the blaze-test is a death-test will, if he pursues the inquiry under more favourable conditions, enable him to discover further that the test can be employed as a 'measure of vitality' in particular cases more or less difficult. We have hitherto applied the test quantitatively only in cases selected as being the most easy and best adapted to the acquisition of comparable numbers by the fewest number of trials, *e.g.*, to seeds fresh and old, to parts of plants presumably more or less active, or of which the activity has been

[1] 'Apparent Fallacies of Electrical Response in Cotton Plants,' by W. Laurence Balls, M.A., *Annals of Botany*, January 1913, p. 103.

more or less reduced by means of anæsthetics. We have not been sanguine enough to attempt to measure the vitality of a given set of plants by applying the test to its roots; we have not even ventured to attack preliminary questions, such as the comparative vitality of roots and stems or of their different parts. In spite of the fact that we are able to work under favourable conditions as regards apparatus and method, we are only too familiar with the difficulty of securing uniformity of experimental conditions during the uninterrupted periods of time required for the systematic recording of a sufficient number of data. We have, therefore, refrained from embarking upon difficult problems such as that proposed to himself by Mr. Balls, although we are by no means convinced that it is incapable of solution after its necessary preliminaries have been mastered, and provided the observer can then devote to it the necessary time and attention. But as a practical proposition it certainly cannot be solved by sporadic or summary experiments such as are sufficient to establish the validity of its principle.

Hitherto our reports have been directed to the establishment of the method in principle, and in this respect we believe ourselves to have been successful; we have shown, *e.g.*, that the voltage of blaze-currents and the vitality of seeds decline *pari passu* with their age.

Our present report contains a detailed account of individual observations carried out during the months of July and August to serve as an indication and sample of the procedure we think necessary to follow in working out the test as a practical method of measuring the vitality of seedlings.

A repetition of the description of method, precautions, results, &c., is not possible now; we must refer for such description to previous publications, more especially to an article in the Journal of the Linnean Society, Vol. XXXVII., on the blaze-currents of vegetable tissues, and to my lectures on 'Signs of Life' published by John Murray, 1903.

It is, however, necessary to say in preface to the following detailed protocols:

1. That excitation by a single induction shock must be of given constant strength, not too weak when little or no response is obtained, nor too strong when after a large response the subsequent excitability is impaired.

2. That it is convenient to have in circuit two galvanometers of different sensitiveness, so that small responses are read upon the more sensitive, large responses upon the less sensitive galvanometer. In the protocols G_1 is a less sensitive galvanometer of 5,000 ohms, G_2 is a more sensitive galvanometer of 70,000 ohms.

3. The voltage of response and the resistance in circuit are to be calculated from the deflections through the plant and through a megohm of a known fraction (one-hundredth) of a volt.

Observation 1. *Seedlings of Pea* (Pisum sativum), *three weeks old. July 29. Freshly cut.*

With 'weak' induction shocks (IV–VII). With 'strong' induction shocks (VIII–XI).

	I Accid. Curr.	II $\frac{1}{100}$	III ∴ R ×1000	IV Exc. 1000+ ⟶	V ∴ volt. ×0·0001	VI Exc. 1000− ⟵	VII ∴ volt.	VIII Exc. 5000+ ⟶	IX ∴ volt.	X Exc. 5000− ⟵	XI ∴ volt. ×0·0001	XII $\frac{1}{100}$	XIII ∴ R ×1000
G_1	—	5	—	+10	+200	{+5 −5}	{+100 −100}	+15	+300	+10	+200	5	—
G_2	−330	50	540	+ off	—	{+50 −50}	—	+ off	—	+ off	—	50	540
G_1	—	5	—	+8	+160	−10	−200	+12	+240	−15	−300	6	—
G_2	−150	55	491	+ off	—	—	—	—	—	—	—	60	450
G_1	—	5	—	+10	+200	−5	—	+20	+400	−14	−280	—	—
G_2	−340	50	540	+ off	—	−50	−100	+ off	—	− off	—	50	540
G_1	—	6	—	−10	−167	−17	−283	+12	+200	−15	−250	—	—
G_2	—	60	450	− off	—	− off	—	+ off	—	− off	—	65	415
G_1	—	4	—	+7	+175	−7	−175	+10	+250	−12	−300	—	—
G_2	+100	40	675	+ off	—	− off	—	+ off	—	—	—	40	675
G_1	—	9	300	+11	+122	−6	−67	+33	+367	−17	−189	9	300
G_2	−150	off	—	—	—	—	—	—	—	—	—	—	—
G_1	—	8	337	+15	+187	−9	−112	+30	+375	−20	−250	9	300
G_2	—	off	—	—	—	—	—	—	—	—	—	—	—
					173		148		299		253		

Average response = 0·0161 volt (V, VII); 0·0276 volt (IX, XI).

Observation 2. *Seedlings of Pea; same crop. July 30. The day after section.*

				'Weak.'				'Strong.'					
	I Accid. Curr.	II $\frac{1}{100}$	III ∴ R ×1000	IV Exc. 1000+ ⟶	V ∴ volt. ×0·0001	VI Exc. 1000− ⟵	VII ∴ volt.	VIII Exc. 5000+ ⟶	IX ∴ volt.	X Exc. 5000− ⟵	XI ∴ volt. ×0·0001	XII $\frac{1}{100}$	XIII ∴ R ×1000
G_1 G_2	— +130	5 50	— 540	+8 + off	+160 —	−10 − off	−200 —	+20 + off	+400 —	−30 − off	−600 —	6 60	— 450
G_1 G_2	— —	— 35	— 771	— +20	— +57	−14 − off	−400 —	+10 + off	+286 —	−17 − off	−486 —	5 50	— 540
G_1 G_2	— —	— 45	— 600	−12 − off	−267 —	−8 − off	−178 —	+20 − off	+444 —	−10 − off	−222 —	5 50	— 540
G_1 G_2	— —	8 off	337 —	— +10	— +12	−11 − off	−138 —	+24 + off	+300 —	−30 − off	−375 —	9 off	300 —

Average = $\underbrace{124 \qquad 229}_{0\cdot0176 \text{ volt.}}$ $\qquad$ $\underbrace{356 \qquad 421}_{0\cdot0389 \text{ volt.}}$

Observation 3. *Seedlings of Pea. August 2. The fourth day after section.*

'Strong.' (VIII–XI)

	I Accid. Curr.	II $\frac{1}{100}$	III ∴ R	IV Exc. 1000+ ⟶	V ∴ voltage	VI Exc. 1000− ⟵	VII ∴ voltage	VIII Exc. 5000+ ⟶	IX ∴ voltage	X Exc. 5000− ⟵	XI ∴ voltage	XII $\frac{1}{100}$	XIII ∴ R
G_1 G_2	— —	— 55	— 490	— —	— —	— —	— —	+26 + off	+436 —	−18 − off	−330 —	— 60	— 450
G_1 G_2	— —	— 60	— 450	— —	— —	— —	— —	+16 + off	+270 —	−25 − off	−417 —	— 65	— 415
G_1 G_2	— —	— 30	— 900	— —	— —	— —	— —	— +40	— +133	−12 − off	−400 —	— 40	— 675
G_1 G_2	— —	— 40	— 675	— —	— —	— —	— —	+12 + off	+300 —	−21 − off	525 —	— 60	— 450

$$\text{Average} = \underbrace{285 \qquad 418}_{0{\cdot}0351 \text{ volt.}}$$

Observation 4. *Seedlings of Pea; five weeks old; drooping after a fortnight in the laboratory atmosphere.* *August* 16, 1913.

	I Accid. Curr.	II $\frac{1}{100}$	III ∴ R	IV Exc. 1000+ ⟶	V ∴ voltage	VI Exc. 1000— ⟵	VII ∴ voltage	VIII Exc. 5000+ ⟶	IX ∴ voltage	X Exc. 5000— ⟵	XI ∴ voltage	XII $\frac{1}{100}$	XIII ∴ R
G_1	—	—	—	—	—	—	—	—	—	—	—	—	—
G_2	100	40	675	—	—	—	—	+18	+45	−12	−30	30	900
G_1	—	—	—	—	—	—	—	—	—	—	—	—	—
G_2	0	25	1080	—	—	—	—	+5	+20	−7	−38	35	771
G_1	—	—	—	—	—	—	—	—	—	—	—	—	—
G_2	250	25	1080	—	—	—	—	−40	−160	−60	−240	35	771
G_1	—	—	—	—	—	—	—	—	—	—	—	—	—
G_2	0	25	1080	—	—	—	—	+20	+80	−20	−80	33	818
G_1	—	—	—	—	—	—	—	—	—	—	—	—	—
G_2	50	30	900	—	—	—	—	+5	+16	−12	−40	30	900

Average of 5 trials .... 0·0064 0·0086

Average of 10 trials........... $\underbrace{\qquad\qquad}_{0·0075}$

(To tetanisation the average of 10 trials gave 0·0134 volt.)

OBSERVATION 5. *Seedlings of Sunflower* (Helianthus annuus), *three weeks old. July* 29. *Freshly cut.*

	I Accid. Curr.	II $\frac{1}{100}$	III ∴ R	IV Exc. 1000+ ⟶	V ∴ voltage	VI Exc. 1000− ⟵	VII ∴ voltage	VIII Exc. 5000+ ⟶	IX ∴ voltage	X Exc. 5000− ⟵	XI ∴ voltage	XII $\frac{1}{100}$	XIII ∴ R
G_1 G_2	0	— 35	— 754	+7 + off	+200 —	— −35	— −100	— −45	— −128	−14 − off	−400 —	— 50	— 540
G_1 G_2	−100	— 40	— 675	— −10	— −20	— −50	— −120	— −20	— −50	−10 − off	−250 —	— 60	— 450
G_1 G_2	−100	— 50	— 540	— +50	— +100	— −40	— −80	+8 + off	+160 —	−10 − off	−200 —	8 —	370 —
G_1 G_2	+400	— 40	— 675	+7 + off	+174 —	+6 + off	+150 —	+13 + off	+333 —	−10 − off	−250 —	— 55	— 491
G_1 G_2	+250	— 50	— 540	— −20	— −40	— −20	— −40	+8 + off	+160 —	−12 − off	−240 —	7 —	380 —

	107	98		166	268
Average =	$\underbrace{\qquad}$ 0·0102 volt.			$\underbrace{\qquad}$ 0·0217 volt.	

OBSERVATION 6. *Seedlings of Sunflower ; same crop ; three weeks old. July 30. The day after section.*

	I Accid. Curr.	II $\frac{1}{100}$	III ∴ R	IV Exc. 1000+ —→	V ∴ voltage	VI Exc. 1000— ←—	VII ∴ voltage	VIII Exc. 5000+ —→	IX ∴ voltage	X Exc. 5000— ←—	XI ∴ voltage	XII $\frac{1}{100}$	XIII ∴ R
G_1 G_2	— —	— 30	— 900	+5 + off	+167 —	+5 + off	+166 —	+7 + off	+233 —	−14 — off	−467 —	— 40	— 675
G_1 G_2	— —	— 35	— 771	— −16	— −45	−7 — off	−200 —	— +35	— +100	−13 — off	−371 —	— 50	— 540
G_1 G_2	— —	— 60	— 450	— +40	— +67	— −45	— −75	+8 + off	+133 —	−14 — off	−233 —	7 —	386 —
G_1 G_2	−200	— 35	— 771	— +35	— +100	— −16	— −46	+10 + off	+286 —	−12 — off	−343 —	— 45	— 600
G_1 G_2	+130	— 30	— 900	— −7	— −23	— −60	— −200	−10 — off	−333 —	−10 — off	−333 —	— 35	— 771
					80		137		217		349		
Average =						0·0105 volt.				0·0283 volt.			

OBSERVATION 7. *Seedlings of Sunflower; same crop. August 2. The fourth day after section.*

	I Accid. Curr.	II $\frac{1}{100}$	III ∴ R	IV Exc. 1000+ —→	V ∴ voltage	VI Exc. 1000— ←—	VII ∴ voltage	VIII Exc. 5000+ —→	IX ∴ voltage	X Exc. 5000— ←—	XI ∴ voltage	XII $\frac{1}{100}$	XIII ∴ R
G_1 G_2	— +200	— 16	— 1687	— —	— —	— —	— —	— −14	— −88	— −35	— −220	— 16	— 1687
G_1 G_2	— —	— 30	— 900	— —	— —	— —	— —	— −15	— −50	— −10	— −33	— 40	— 675
G_1 G_2	— —	— 40	— 675	— —	— —	— —	— —	— +50	— +125	−7 — off	−175 —	— 44	— 614
G_1 G_2	— —	— 25	— 1080	— —	— —	— —	— —	— +3	— +12	— −5	— −20	— 25	— 1080
G_1 G_2	— —	— 20	— 1350	— —	— —	— —	— —	— +17	— +85	— −25	— −125	— 25	— 1080

Average = $\underbrace{72 \qquad 115}_{0\cdot0093 \text{ volt.}}$

OBSERVATION 8. *Sunflower Seedlings, five weeks old. August 17, 1913. Kept in the conservatory.*

	I Accid. Curr.	II $\frac{1}{100}$	III ∴ R	IV Exc 1000+ →	V ∴ voltage	VI Exc. 1000− ←	VII ∴ voltage	VIII Exc. 5000+ →	IX ∴ voltage	X Exc. 5000− ←	XI ∴ voltage	XII $\frac{1}{100}$	XIII ∴ R
G_1 G_2	— −200	— 40	— 675	— —	— —	— —	— —	— +15	— +37	— −70	— −175	— 65	— 415
G_1 G_2	— −200	— 35	— 771	— —	— —	— —	— —	— +45	— +130	— −30	— −85	— 35	— 771
G_1 G_2	— 0	— 35	— 771	— —	— —	— —	— —	−7 − off	−200 —	−13 − off	−371 —	— 45	— 600
G_1 G_2	— −100	7 —	385 —	— —	— —	— —	— —	−8 − off	−114 —	+25 + off	+350 —	11 —	245 —
G_1 G_2	— −600	— 40	— 675	— —	— —	— —	— —	+6 + off	+150 —	−10 − off	−250 —	— 50	— 540

$$\text{Average} = \underbrace{0{\cdot}0126 \qquad 0{\cdot}0246}_{0{\cdot}0186 \text{ volt.}}$$

Observation 9. *Seedlings of Indian Corn* (Zea Mays), *three weeks old. July* 30, 1912. *Freshly cut.*

	I Accid. Curr.	II $\frac{1}{100}$	III ∴ R	IV Exc. 1000+ ⟶	V ∴ voltage	VI Exc. 1000− ⟵	VII ∴ voltage	VIII Exc. 5000+ ⟶	IX ∴ voltage	X Exc. 5000− ⟵	XI ∴ voltage	XII $\frac{1}{105}$	XIII ∴ R
G_1	—	—	—	—	—	—	—	—	—	—	—	—	—
G_2	−400	20	1350	+10	+50	−3	−15	+30	+150	−4	−20	20	1350
G_1	—	—	—	—	—	—	—	—	—	—	—	—	—
G_2	+20	25	1080	+5	+20	−10	−40	+25	+100	−45	−180	25	1080
G_1	—	—	—	—	—	—	—	—	—	—	—	—	—
G_2	−10	40	675	+30	+75	+20	+50	−20	+50	−60	−150	35	754
G_1	—	—	—	—	—	—	—	—	—	—	—	—	—
G_2	−100	28	964	−8	−30	−10	−35	+20	+66	+10	+35	30	900
G_1	—	—	—	—	—	—	—	—	—	—	—	—	—
G_2	+20	38	710	+5	+13	−25	−65	+50	+125	−35	−87	40]	675

$$\text{Average} = \underbrace{38 \qquad\qquad 41}_{0\cdot0040 \text{ volt.}} \qquad\qquad \underbrace{98 \qquad\qquad 90}_{0\cdot0094 \text{ volt.}}$$

OBSERVATION 10. *Seedlings of Indian Corn; the same crop. August 2, 1912. Third day after section.*

	I Accid. Curr.	II $\frac{1}{100}$	III ∴ R	IV Exc. 1000+ ⟶	V ∴ voltage	VI Exc. 1000− ⟵	VII ∴ voltage	VIII Exc. 5000+ ⟶	IX ∴ voltage	X Exc. 5000− ⟵	XI ∴ voltage	XII $\frac{1}{100}$	XIII ∴ R
G_1 G_2	— —	— 30	— 900	— —	— —	— —	— —	— −25	— −83	— −20	— 71	— 30	— 900
G_1 G_2	— —	— 25	— 1080	— —	— —	— —	— —	−7 — off	−280 —	−7 — off	−280 —	— 35	— 771
G_1 G_2	— —	— 40	— 675	— —	— —	— —	— —	−12 — off	−300 —	— −35	— −87	— 50	— 540
G_1 G_2	— —	— 35	— 771	— —	— —	— —	— —	— −30	— −86	−12 — off	−340 —	— 40	— 675

$$\text{Average} = \underbrace{187 \qquad\qquad 194}_{0{\cdot}0190 \text{ volt.}}$$

Observation 11. *Seedlings of Bean* (Vicia faba), *three weeks old; freshly cut. July* 28, 1913.

	I Accid. Curr.	II $\frac{1}{100}$	III $\therefore$ R	IV Exc. 1000+ $\rightarrow$	V $\therefore$ voltage	VI Exc. 1000− $\leftarrow$	VII $\therefore$ voltage	VIII Exc. 5000+ $\rightarrow$	IX $\therefore$ voltage	X Exc. 5000− $\leftarrow$	XI $\therefore$ voltage	XII $\frac{1}{100}$	XIII $\therefore$ R
G_1 G_2	— −150	8 —	337 —	−6 —	−75 —	−5 —	−62 —	+25 —	+312 —	−12 —	−150 —	8 —	337 —
G_1 G_2	— −100	15 —	180 —	+10 —	+67 —	+3 —	+20 —	+40 —	+267 —	−26 —	−173 —	15 —	180 —
G_1 G_2	— —	15 —	180 —	— +20	— +13	−25 − off	−167 —	+30 + off	+200 —	−40 − off	−267 —	18 —	150 —
G_1 G_2	— +50	15 —	180 —	— +35	— +23	— −30	— −20	+25 + off	+167 —	−15 − off	−100 —	15 —	180 —
G_1 G_2	— —	7 —	386 —	+9 + off	+130 —	+11 + off	+160 —	+20 + off	+286 —	−6 − off	−86 —	9 —	300 —
					0·0062		0·0086		0·0246		0·0155		

Average = $\underbrace{0{\cdot}0062 \quad 0{\cdot}0086}_{0{\cdot}0074\text{ volt.}}$ $\qquad \underbrace{0{\cdot}0246 \quad 0{\cdot}0155}_{0{\cdot}0200\text{ volt.}}$

Observation 12. *Seedlings of Bean; five weeks old, i.e., three weeks in conservatory, then two weeks in laboratory. August* 16, 1913.

	I Accid. Curr.	II $\frac{1}{100}$	III ∴ R	IV Exc. 1000+ ⟶	V ∴ voltage	VI Exc. 1000− ⟵	VII ∴ voltage	VIII Exc. 5000+ ⟶	IX ∴ voltage	X Exc. 5000− ⟵	XI ∴ voltage	XII $\frac{1}{100}$	XIII ∴ R
G_1 G_2	— 170	— 35	— 771	— —	— —	— —	— —	— 0	— 0	— 0	— 0	— 35	— 771
G_1 G_2	— 150	— 40	— 675	— —	— —	— —	— —	— −10	— 25	— −20	— 50	— 35	— 771
G_1 G_2	— 0	— 30	— 900	— —	— —	— —	— —	— +5	— 17	— −7	— 14	— 35	— 771
G_1 G_2	— 0	— 40	— 675	— —	— —	— —	— —	— −8	— 20	— −15	— 38	— 30	— 900
G_1 G_2	— 300	— 30	— 900	— —	— —	— —	— —	— +15	— 50	— −20	— 67	— 33	— 818

$$\text{Average} = \underbrace{0{\cdot}0022 \qquad 0{\cdot}0034}_{0{\cdot}0028 \text{ volt.}}$$

(To tetanisation the average of 10 trials gave 0·0108 volt.)

SUMMARY.

—	—	—	Weak	Strong	Remarks
July 29 ...	Obs. 1	Pea (fresh)	161	276	
„ 30 ...	„ 2	, (2nd day)	176	389	
Aug. 2 ...	„ 3	„ (4th day)	285	418	
„ 16 ...	„ 4	Pea (drooping)	64	86	After a fortnight in the laboratory.
July 29 ...	„ 5	Sunflower (fresh)	102	217	
„ 30 ...	„ 6	„ (2nd day)	105	283	
Aug. 2 ...	„ 7	„ (4th day)	72	115	
„ 17 ...	„ 8	„	—	186	After a fortnight in conservatory.
July 30 ...	„ 9	Indian corn (fresh)	40	94	
Aug. 2 ...	„ 10	„ (3rd day)	—	190	
July 28 ...	„ 11	Bean (fresh)	74	200	
Aug. 16 ...	„ 12	„ (drooping)	—	28	After a fortnight in the laboratory.

The response of the cut seedlings was at first increased ; it diminished when the plants began to droop in a bad atmosphere.

Observation 13. *An experiment made to determine the alteration of blaze-current (? = the deterioration of plant-activity) caused upon Seedlings of Pea, Bean, and Sunflower by immersion in n/100 and n/10 H_2SO_4.*

		I Accid. Curr.	II $\frac{1}{100}$	III ∴ R	IV Exc. 1000+ ⟶	V ∴ voltage	VI Exc. 1000− ⟵	VII ∴ voltage	VIII Exc. 5000+ ⟶	IX ∴ voltage	X Exc. 5000− ⟵	XI ∴ voltage	XII $\frac{1}{100}$	XIII ∴ R	
Pea	G_1 G_2	— +30	7 —	386 —	+22 + off	314 —	−7 − off	100 —	+22 + off	314 —	−18 − off	257 —	9 —	300 —	Normal Fresh
Bean	G_1 G_2	— −300	10 —	270 —	+18 + off	180 —	+10 + off	100 —	+35 + off	350 —	−15 − off	150 —	15 —	180 —	
Sun-flower	G_1 G_2	— −30	6 —	450 —	— —	— —	— —	— —	+18 + off	300 —	−17 − off	283 —	8 —	337 —	
Pea	G_1 G_2	— —	10 —	270 —	— +14	— 14	— −30	— 30	+15 + off	150 —	−24 − off	240 —	9 —	300 —	After immersion for 1 hour in H_2SO_4 n/100
Bean	G_1 G_2	— —	15 —	180 —	— —	— —	— —	— —	+28 + off	187 —	−16 − off	107 —	20 —	135 —	
Sun-flower	G_1 G_2	— —	9 —	300 —	— —	— —	— —	— —	+9 + off	100 —	−10 − off	111 —	10 —	270 —	

Observation 13.—*continued.*

		I Accid. Curr.	II $\frac{1}{100}$	III ∴ R	IV Exc. 1000+ ⟶	V ∴ voltage	VI Exc. 1000— ⟵	VII ∴ voltage	VIII Exc. 5000— ⟶	IX ∴ voltage	X Exc. 5000— ⟵	XI ∴ voltage	XII $\frac{1}{100}$	XIII ∴ R	
Pea	G_1	—	13	208	—	—	—	—	+16	123	−16	123	10	270	After immersion for 1 hour in H_2SO_4 n/10
	G_2	—	—	—	+12	9	−50	38	— off	—	— off	—	—	—	
Bean	G_1	—	24	113	—	—	—	—	—	—	—	—	25	108	
	G_2	—	—	—	+4	2	+7	3	+18	7	+40	16	—	—	
Sun-flower	G_1	—	14	193	—	—	—	—	—	—	—	—	15	180	
	G_2	—	—	—	—	—	—	—	−10	7	−40	28	—	—	
Pea	G_1	—	15	180	—	—	—	—	—	—	—	—	15	180	After immersion for 24 hours in water.
	G_2	+10	—	—	0	0	0	0	−2	1	−2	1	—	—	
Bean	G_1	—	13	208	—	—	—	—	—	—	—	—	13	208	
	G_2	+50	—	—	—	—	—	—	−3	2	−8	6	—	—	
Sun-flower	G_1	—	7	386	—	—	—	—	—	—	—	—	7	386	
	G_2	+100	—	—	—	—	—	—	−3	4	+1	1	—	—	

The foregoing data, scanty and imperfect as they are, indicate a general relation between plant-vitality and voltage of blaze-current. But our principal object has been to indicate in detail the systematic lines along which further observations are required from which—multiplied a hundredfold—it can become legitimate to infer in given instances *how much* the blaze-current actually varies with varying degrees of plant-activity and (?) plant-health under given conditions.

The Structure and Function of the Mammalian Heart.—Report of the Committee, consisting of Professor FRANCIS GOTCH *(Chairman) and* Professor STANLEY KENT *(Secretary), appointed to make further researches thereon.*

THE investigation forms a portion of work which has been in progress for some years.

The particular problem attacked this year has been the question:—

'Is the conducting path between auricle and ventricle in the mammalian heart single, or is it multiple?'

The problem has been attacked both from the histological and from the experimental side.

The histological results have shown the existence of an alternative anatomical path, whilst the experimental findings are most easily explained on the supposition that this alternative path becomes functional under certain conditions.

The results are of interest theoretically, and also from the point of view of the clinician, who has found it impossible to explain—on the supposition of a single path—conditions which occur not infrequently in cases of cardiac disease.

Some of the results are being published in the Proceedings of the Royal Society, but more work is necessary before the full details can be available. For this further work a new grant is being sought.

Colour Vision and Colour Blindness.—Report of the Committee, consisting of Professor E. H. STARLING *(Chairman)*, Dr. F. W. EDRIDGE-GREEN *(Secretary)*, Professor LEONARD HILL, Professor A. W. PORTER, *and* Professor A. D. WALLER. *(Drawn up by the Secretary.)*

A CONSIDERABLE amount of work in colour vision has been done by individual members of the Committee. The inadequacy of the wool test even with additional colours as an efficient test for colour blindness is now established. On April 1 of this year the Board of Trade adopted a lantern test for colour blindness in addition to the wool test. The total number of men examined by the Board in colour vision from April 1 to May 31 was 1,689, and of these 105, or 6·22 per cent., failed. Of the 105 failures, 55 failed in both the wool test and lantern test, and 50 in the lantern only. None failed in the wool test only.

The four chief colour names (red, yellow, green, and blue) must be used in any test for colour blindness, and if a daylight test be required, the bead test of Edridge-Green is preferable. The chief difficulty from a practical point of view is the line at which rejection should take place, as there is every grade of transition between total colour blindness and the normal colour sense. If a large number of persons be examined with the Edridge-Green lantern about 25 per cent. show defects of colour perception. In the majority of cases these defects are slight, therefore it is necessary to know the nearest distance at which a coloured light must be recognised—*i.e.*, the exact degree of colour weakness which is permissible—and that the line of rejection should be fixed accordingly. It is obvious that any man having even a slight defect of colour perception is not quite as efficient as one not possessing this defect; this particularly applies to the shortening of the red end of the spectrum, which prevents the recognition of red light at the normal distance, particularly when obscured by fog.

The Committee recommends that it be reappointed.

The Ductless Glands.—Report of the Committee, consisting of Sir E. A. SCHÄFER (*Chairman*), Professor SWALE VINCENT (*Secretary*), Professor A. B. MACALLUM, Dr. L. E. SHORE, *and* MRS. W. H. THOMPSON. (*Drawn up by the Secretary.*)

THE Secretary has been continuing his investigations upon various points connected with the physiology and the comparative anatomy of the ductless glands.

A study of the distribution and the detailed histology of the accessory cortical adrenal bodies has been commenced, but as this involves a large amount of serial section cutting, the work has not progressed very far, and there are no new facts to report at this stage.

An investigation into the histological changes in the thyroids and parathyroids (along with some of the other ductless glands) under varying physiological and pathological conditions (different diets, starvation, poisons, &c.) has been undertaken, and a large amount of material for examination has been collected.

Mr. Cameron has been testing Hunter's method of iodine estimation in organic substances.[1] It is satisfactory for moderate amounts, such as are found in the sheep's thyroid. It is not satisfactory for very slight traces. Comparison tests are being made with this method and some more recent modifications of it in the hope of finding a rigid test for traces of iodine (one part in 500,000).

An initial attempt has been made to correlate other tissues with the thyroid as regards iodine content. No definite results have yet been obtained, but traces (of a second lower order of magnitude) appear to be present in other organs of the series of ductless glands (*e.g.*, testes, ovary, adrenal, thymus).

[1] *J. Biol. Chem.*, 1910.

The presence of iodine in the thyroid of frogs, fishes, and reptiles is under investigation, and it is hoped to have some publishable data shortly. This comparative work is being carried out with the assistance of Mrs. Thompson.

This chemical work is preliminary to a thorough investigation (by means of metabolism experiments) of the rôle of iodine in the animal economy.

The Committee ask to be reappointed, with a grant of 40*l*.

The Dissociation of Oxy-Hæmoglobin at High Altitudes.—Report of the Committee, consisting of Professor E. H. STARLING *(Chairman),* Mr. J. BARCROFT *(Secretary), and* Mr. W. B. HARDY.

IN this report the blood will be termed 'mesectic' when the balance of ions in it is such that the dissociation curve of the individual is in its normal position, 'pleonectic'[1] when the curve is so shifted that at any given pressure of oxygen the hæmoglobin takes up more oxygen than under normal circumstances, and 'meionectic' when it takes less than its usual quantity of oxygen.

The curves in this report are calculated from the formula suggested by Hill

$$\frac{y}{100} = \frac{Kx^n}{1 + Kx^n},$$

where y = the percentage saturation of hæmoglobin with oxygen, x = oxygen pressure in mm., K and n are constants for each curve. In human blood n remains 2·5, therefore practically K is the only variable.

The immediate effect of exercise, if sufficiently severe, is to shift the curve in the direction of greater acidity; this may take place even though the carbonic acid tension is reduced.

For instance, the constants of Roberts' mesectic curve are $n = 2{\cdot}5$, $K = {\cdot}00033$, $\log K = \bar{4}{\cdot}5785$, his normal alveolar CO_2 pressure is 40 mm. Some points on his curve would be as follows:—

Percentage saturation .	9·4	22	37	51	62	85·5	95
Pressure of oxygen .	10	15	20	25	30	50	80

After climbing 1,000 feet from sea level in 20 minutes up Carlingford mountain, his curve became meionectic,

$$n = 2{\cdot}5, \quad K = {\cdot}0001805, \quad \log K = \bar{4}{\cdot}2565, \quad CO_2 = 35 \text{ mm.}$$

Percentage saturation .	6	14	24	35	47	76	91
Pressure of oxygen .	10	15	20	25	30	50	80

At slow rates of climbing, 1,000 feet in 45 minutes, Barcroft's blood remained mesectic.

[1] πλεονεκτικός, disposed to take more than one's share. From πλεονεξία, a disposition to take more than one's share (Liddell and Scott). We are indebted to Dr W. M. Fletcher and Mr. Harrison for this nomenclature.

The investigation was undertaken for the purpose of controlling the results of similar climbs at high altitudes. The comparison is as follows:—

1. Altitude up to 15,000 feet produces a lowering in the carbonic acid pressure, nevertheless the blood remains mesectic in the resting subject.

For instance, at the Capanna Margherita [2] on Monte Rosa the day after arrival Roberts' alveolar carbonic acid pressure was 26 mm. The following points determined at these pressures fall on his mesectic curve (see previous paper).

Percentage saturation	.	33	77 calculated from mesectic curve
Percentage saturation	.	34	73 (observed)
Oxygen pressure .	.	19	41

2. A given degree of meionexy is produced by a lesser degree of activity at high altitudes. Thus at Col d'Olen, climbing 1,000 feet, from an altitude of 9,000 feet to 10,000 in 38 minutes, Roberts' curve became as follows:—

$$n = 2{\cdot}5, \quad K = {\cdot}000161, \quad \log K = \bar{4}{\cdot}2068, \quad CO_2 = 36 \text{ mm.}$$

The degree of meionexy is almost identical with that produced at Carlingford when climbing the same height in 20 minutes.

3. A greater degree of meionexy is produced by a given amount of exercise at high altitudes. Thus Barcroft, climbing from 9,000 feet to 10,000 feet in 45 minutes at Col d'Olen, moved the constants of his curve as follows:—

Mesectic curve . $n = 2{\cdot}5$, $K = {\cdot}000292$, $\log K = \bar{4}{\cdot}4654$
Meionectic curve $n = 2{\cdot}5$, $K = {\cdot}000191$, $\log K = \bar{4}{\cdot}2810$, $CO_2 = 33$ mm.

Corresponding points would be

Percentage saturation	9	20	34	48	58	84	94 mesectic
Percentage saturation	6	14	26	37	48	77	92 meionectic
Oxygen pressure .	10	15	20	25	30	50	80

Climbing from sea level to 1,000 feet at Carlingford also in 45 minutes no certain degree of meionexy could be ascertained. The following points were observed:—

CO_2 pressure 38 mm.
Percentage saturation 58 calculated from mesectic curve.
Percentage saturation 56 per cent.—55 per cent. observed.
Oxygen pressure 30 mm.

The Effect of Low Temperatures on Cold-blooded Animals.—Report of the Committee, consisting of Professor SWALE VINCENT *(Chairman) and* Mr. A. T. CAMERON *(Secretary). (Drawn up by the Secretary.)*

MESSRS. CAMERON AND BROWNLEE have carried out a number of experiments on frogs (*R. pipiens*) obtained from the neighbourhood

[2] For the amounts of acid added see *Brit. Assoc. Report*, 1911, p. 153.

of Chicago. They freeze at a temperature of 0·44°–0·02° C., in a manner very similar to that of solutions isotonic with their body-fluids. They will survive a temperature of $-1°$ C. They will not survive a temperature of $-1·8°$ C.

The heart-tissue, whether exsected or *in vivo*, of these frogs survives a temperature of $-2·5°$, but is killed by a temperature of $-3·0°$ C. Other observers have shown that frog's muscular tissue will survive a temperature of $-2·9°$ C., while the peripheral nerves are not killed by much lower temperatures. Hence it appears probable that the cause of death is connected with a specific temperature effect on the brain or cord.

Full details of these results will appear shortly elsewhere. It seems desirable to continue these experiments with the same species obtained at different seasons, and with some tropical species.

The Committee therefore request to be reappointed, with a grant of 10*l.*

Calorimetric Observations on Man.—Report of the Committee, consisting of Professor J. S. MACDONALD (*Chairman*), Dr. F. A. DUFFIELD (*Secretary*), *and* Dr. KEITH LUCAS, *appointed to make Calorimetric Observations on Man in Health and in Febrile Conditions.*

CONTINUING the work reported on last year a large number of experiments have been performed, in which the total heat-production has been measured and contrasted with the mechanical work done. A statement dealing with the results of these experiments has been accepted for publication in the Proceedings of the Royal Society. In each of these experiments a subject enclosed in the calorimeter cycled against the known resistance of a definite brake at a uniform revolution-rate for a period of two hours. Again, as in last year's experiments, there was a noticeable difference between the measured heat-production of the first and second hour respectively in each experiment. To test the meaning of this apparent difference between the events of the first and second hour arrangements were made early in this year's work to add to the measurements formerly made some means of determining the carbon-dioxide production, and it is upon the progress made in this direction that I have now to make some report.

It will be remembered that in the original Atwater and Benedict calorimeter, from which the details of construction of the body of this instrument in Sheffield have been largely copied, apparatus of a very perfect kind is arranged to deal with the gaseous exchange of the subject. In that instrument the air-steam from the calorimeter is pumped through a system of absorption vessels, and thus freed from carbon-dioxide, and water is pumped back into the calorimeter with the addition of just so much oxygen as suffices to maintain the normal barometric pressure of the enclosed atmosphere. From the altered weight of the absorption vessels and of the oxygen-cylinder exact data are obtained as to the output of carbon-dioxide and aqueous vapour and the intake of

oxygen. Largely from reasons of economy no attempt has been made to copy this procedure and apparatus. In place of the closed circuit of tubes through which air is led away from and back to the calorimeter we have an open system. By a length of suitably wide tubing the air-entrance is carried to a point at some little distance from the calorimeter, and therefore some distance from the air disturbed by the presence of the observers. A powerful fan driving a large current of air across the path of this tube further secures this separation. Similarly by a length of tubing the air-exit is carried into another room, in which the pump and gas meter are situated. The entrance and exit are thus widely separated.

The tubes carrying the 'entering' and the 'leaving' air have each, at a certain point, been subdivided into three separate paths, and suitable arrangements made so that sampling-bottles may be inserted or removed from one of these short subdivisions of the air-path. Thus a definite fraction of the air-stream traverses each sampling-bottle, and is always allowed to traverse it for a time sufficient to ensure the complete replacement of its original contents by air similar to that traversing the remaining fraction of the air-path.

In twenty of the experiments in which Professor Macdonald has collected the data of heat-production I have analysed samples of the 'leaving air' obtained in this way. In the earlier cases the 'entering air' was also sampled and analysed, but I found its content of carbon-dioxide so relatively constant that I abandoned dealing with it for the present. In thirteen of these experiments the 'leaving air' was dealt with as follows:—The sample-bottles were of large size (7 to 8 litres), to the large volume of air contained in them baryta solution was added, shaken up and allowed to stand, and then titrated with a known strength of oxalic acid. In the application of this 'Pettenkofer method' I owe much to the assistance of Mr. W. J. Jarrard, B.Sc. The results obtained by this method were consistent in the different experiments, and in each experiment provided results giving, when plotted out, comparatively smooth curves, which showed the output of carbon-dioxide from the calorimeter as gradually increasing towards a level reached somewhere before the end of the first hour of cycling and then sustained for the second hour.

In the remaining seven of these experiments I have replaced this method by a volumetric method, using the apparatus devised by Dr. J. S. Haldane (large laboratory type), substituting smaller sampling vessels of approximately 70 c.c. capacity as now sufficient. Up to the present the plotted curves of results obtained by this method have not been as smooth as those originally obtained, but this will be improved upon when the air-stream has been diminished so as to enable me to deal with larger percentage values. The quantity of air traversing the system has varied from 300-410 cubic feet per hour, and will next year be substantially diminished in the interests of these gas-analyses, and peculiarly so because of oxygen determinations, which will then be instituted. This desire to deal later with the oxygen values explains a preference for the Haldane method.

Adding to the results of such experimental determinations of the

carbon-dioxide output, corrections for the amount of carbon-dioxide stored within the large space of the calorimeter (175 cubic feet approx.; see below), the plotted curves are practically converted into lines parallel to the abscissa—that is to say, the difference apparently existing between the first and second hours of cycling disappears. It would seem then, as far as these experiments go, that the total transformation of energy is the same in the two cases, varying with the amount of mechanical work performed alone, and not with the length of time during which this performance has been continued. The bearing of this conclusion upon the still continuing differences in the measurements of apparent total heat-production in the first and second hour has been dealt with by Professor Macdonald in the communication already referred to.

A large number of special experiments (25) have been performed to obtain an experimentally-derived method for estimating the precise value of these corrections for internal storage of carbon-dioxide, in which the experimental subject has been replaced by a measurable source of carbon-dioxide production. Such experiments are still in progress, and will be described better at a later period; their results are such, however, as to promise considerable security in dealing with the storage corrections.

Incidentally the internal volume of the calorimeter has been measured, carbon-dioxide gas being injected until a certain definite percentage composition was attained in the well-mixed atmosphere within the calorimeter, and the total quantity present then measured as it was withdrawn in the air-current. The figure obtained by this method, 176 cubic feet, closely coincides with that obtained from measurements of the average dimensions of the chamber (174 cubic feet). This coincidence in the two sets of measurements is naturally accepted as evidence of accuracy of the means used for measuring the carbon-dioxide output from the calorimeter.

The Investigation of the Jurassic Flora of Yorkshire.—Report of the Committee, consisting of Professor A. C. SEWARD (*Chairman*), Mr. H. HAMSHAW THOMAS (*Secretary*), Mr. HAROLD WAGER, *and* Professor F. E. WEISS.

THE work of the year has been very satisfactory. The rich plant-beds exposed on and near Roseberry Topping have been carefully examined and have yielded a large number of interesting forms, several of which are new to Yorkshire. These plant-bearing strata are at the base of the Estuarine series, and may be probably regarded as Liassic in age and older than any of the previously known plant-beds. Among the specimens found are many beautifully preserved examples of two species of *Thinnfeldia*, a species of *Ptilozamites*, a species of *Hausmannia*, and a new conifer. A brief sketch of the flora has been given by the Secretary of the Committee in the 'Naturalist' (p. 198, 1913). The occurrence of the plant-beds in the locality has been studied and proves to be very local. Some plant remains have been found

in the Middle Estuarine beds of Eston Hill, one of the northern outliers of the Cleveland Hills.

The Gristhorpe bed continues to provide interesting forms. The excavations which have been carried on this year in Cayton and Gristhorpe Bays have resulted in the discovery of several new species. Among them is a new type of Ginkgoalian leaf, which has been described as *Eretmophyllum pubescens*, gen. et sp. nov.,[1] and this type has also been recognised at Whitby. A female flower of the *Williamsonia* type, new to England and probably allied to the *Wieldandiella angustifolia* of Nathorst, has been found, also a new fern and some seeds and cones of new types. Many specimens of the rare species *Beania gracilis*, Carr., *Baiera Lindleyana*, Schimp., and *Cladotheca undans*, L. and H., have been found, also some interesting forms of *Czekanowskia*. Material has also been obtained for the study of the cuticular structure of the Jurassic *Cycadophyta*, the results of which will be published shortly.

The experience of the last few years has justified the opinion that many new forms might be found by systematic search, even in the oldest and most worked localities. During the last three years the Secretary of the Committee, aided materially by grants made by the Association, has succeeded in obtaining about twenty-two species new to the Jurassic Flora of Yorkshire, which will be described in due course.

The Flora of the Peat of the Kennet Valley.—Interim Report of the Committee, consisting of Professor F. KEEBLE *(Chairman)*, Miss M. C. RAYNER *(Secretary)*, Professor F. W. OLIVER, *and* Professor F. E. WEISS, *appointed for the investigation thereof.*

THERE are extensive deposits of peat in the Valley of the Kennet and evidence of old peat workings in the neighbourhood of Newbury.

The peat occurs from four to five feet below the surface and may be as much as eight feet below the present dry-weather level of the river. It varies in thickness from a few inches to about ten feet.

The present investigation was undertaken to map the distribution of some of these peat deposits and to investigate and report on the plant and animal remains which they contain.

The following data have been obtained:—

(1) A coarse flint gravel underlies the peat in all the completed sections, at depths varying from six feet to fifteen feet.

This gravel may mark an early type of infilling of the valley, but is more probably part of a gravel terrace formed during Palæolithic times which has since been buried beneath the rising flood plain. There is at present no certain clue as to its age.

(2) The peat is of the 'valley' type, *i.e.*, it includes varying amounts of fine silt and contains land and fresh-water shells. It is

[1] *Proceedings Cambridge Philosophical Society*, 1913, p. 256.

mixed and sometimes interstratified with a loose calcareous tufa which seems to be of concretionary origin, the calcareous matter having surrounded the decaying vegetation in a way suggestive of the action of a 'petrifying' spring.

This tufa is not associated with any special abundance of shells, but seems to occur at a level in the peat to which saturation may rise in winter, but below which it falls in dry weather. In one section the tufa occurs mainly in a layer about two feet thick, separating the peat into two distinct layers, which are slightly different in character and give some indication of containing remains of a different fauna and flora.

(3) The following remains have been collected from the peat and identified:—

Bones of wild boar, red deer, and beaver; shells of numerous species of land and fresh-water Gasteropods.

The remains of beaver were found in the lowest layer of peat, twelve feet below the surface, and are of some interest as suggesting that beaver dams may have been a factor in the formation of local deposits of peat.

Plant remains are abundant but badly preserved. The following have been identified:—

Trunks and roots of *Alnus* and *Betula*; rhizomes of *Phragmites* and *Equisetum* sp. (locally very abundant); seeds of *Menyanthes trifoliata*; *Carex* sp.; *Potentilla* sp.

Many more borings and sections are required in order to map the distribution, and to determine with certainty whether there were any marked changes of flora during the formation of the peat. Owing to the occurrence of the peat below the present river level and the wet winter and spring of 1912-1913, field work was impossible during the greater part of this year.

The Committee therefore ask for reappointment for another year, with a renewal of the grant of 15*l.* made last year.

The Vegetation of Ditcham Park, Hampshire.—Interim Report of the Committee, consisting of Mr. A. G. Tansley *(Chairman)*, Mr. R. S. Adamson *(Secretary)*, Dr. C. E. Moss, *and* Professor R. H. Yapp, *appointed for the investigation thereof.*

Considerable progress has been made with the investigations. A general survey has been made of the area, which consists of chalk, partly covered with clays, in part calcareous and in part leached. The principal plant communities have been mapped. The following are the most noticeable ones on the area:—

(i) *On chalk.—Beech* wood with and without *Taxus*. All stages between *beech* wood and *chalk scrub*, passing through *Taxus* wood and *ash* wood. The *chalk scrub* is partly retrogressive and partly progressive. *Chalk grassland*, with transitions to scrub, either retrogressive or progressive.

Calcareous coppice, both with standards of beech and ash and without.

(ii) *On clays.*—Coppiced woods, showing transition stages from calcareous coppice where the soil is thin to coppiced woods with good oak standards and hazel or ash coppice, and many non-calcareous elements in the vegetation, such as *Pteridium* and *Holcus mollis.*

Grassland on clay with local patches of heath grassland, and to a very limited extent of heath.

Special attention has been paid to natural regeneration of beech woods. Large quantities of fruit were produced in 1912, and the fate of the seedlings is being watched and investigated.

Two areas where beech wood and chalk scrub adjoin chalk grassland have been fenced in to exclude rabbits and are receiving special attention. Very considerable differences are observable on the two sides of the fence; the most striking being the height of the pasture plants. Outside the turf is cropped like a lawn, while inside, in June, there was a luxuriant growth averaging 12 to 18 inches in height.

Of more experimental work special attention has been paid so far to evaporation. A large series of evaporimeters has been established in selected parts of the woods and readings taken regularly. Temperature and humidity (by wet and dry bulb thermometer) are also being recorded along with the evaporation. Very considerable differences of evaporation, accompanied by changes in the ground vegetation, have been noted in beech woods at different levels of the chalk escarpment and on the tops of the hills.

Preliminary investigations have also been carried out on the light intensity and on the different soils, which will be pursued in more detail in the immediate future.

Botanical Photographs.—Report of the Committee, consisting of Professor F. W. OLIVER (*Chairman*), Professor F. E, WEISS (*Secretary*), Dr. W. G. SMITH, Mr. A. G. TANSLEY, Dr. T. W. WOODHEAD, *and* Professor R. H. YAPP, *for the Registration of Negatives of Photographs of Botanical Interest.*

OWING to the small demand made for the loan of negatives of botanical interest, due, no doubt, to the large number of photographs and lantern slides available from various dealers, the Committee considers that it is unnecessary now to continue its labours. It recommends that all prints of ecological interest should be handed to the newly founded Ecological Society, and that all other prints should be housed in the Botanical Department of the University of Manchester, where they will continue to be available for further reference. It considers, however, that the Committee might now be dissolved.

Report[1] *of the Committee, consisting of—*

Dr. G. A. AUDEN (*Chairman*), Mr. G. F. DANIELL (*Secretary*), Mr. C. H. BOTHAMLEY, Mr. W. D. EGGAR, Professor R. A. GREGORY, Mr. N. BISHOP HARMAN, Mr. J. L. HOLLAND, Professor PRIESTLEY SMITH, *and* Mr. W. T. H. WALSH, *appointed to Inquire into the Influence of School-books upon Eyesight.*

THE Committee was appointed at Portsmouth in 1911, and from the beginning of its investigations has had the advantage of the assistance of Dr. H. Eason, Professor H. R. Kenwood, Mr. R. B. Lattimer, Miss Brown Smith, and Dr. Louisa Woodcock.

In view of the fact that Local Education Authorities are able greatly to influence the selection of school-books, the Committee made an inquiry, on which is based the section of this report headed 'Present Practice of Local Education Authorities.' At the request of the Committee Dr. H. Eason, Mr. Bishop Harman, and Professor Priestley Smith drew up the 'Oculist Sub-Committee's Report.' The typographical section of the report has been revised since its original presentation at Dundee, and to this portion oculists, school medical officers, directors of education, teachers, publishers, printers, and type-founders have contributed. The Committee desires to record its sense of obligation to the pioneer work of Javal.

[1] This report is a revision (involving substantial alterations) of that presented by the Committee in 1912, and is printed from the type in which the report of 1912 was set up, at the request of the Committee, subsequently to its issue in the ordinary type used for the Annual Report of the Association.

The Present Practice of Local Education Authorities in England and Wales.

In a Circular (No. 596) issued by the Board of Education in 1908 the functions of the School Medical Officer are defined. Under the heading of 'Arrangements for attending to the health and physical condition of school children' it is stated that he will advise the Local Education Authority with reference to improvements of the school arrangements. It is further stated in the Circular that 'As regards cases of defective eyesight he will indicate such measures as can be taken to remedy or mitigate the defects by altering the position of the children in the class, or improving the lighting of the school in amount or direction; and he will call attention to the strain imposed on eyesight by the use of too small type in text-books, the teaching of very fine sewing, &c.' There can be no doubt that this suggested advice has in many cases led to an improvement where certain school arrangements have been prejudicial to vision; but hitherto it has not been possible to deal effectively with the provision of satisfactory school text-books.

A circular letter was sent to the Education Authority of each county and county borough stating the objects of the Committee, and asking for information on the following points:—

(1) Whether the eyesight of the children in the schools of the Authority is tested at regular intervals;

(2) Whether advice on the care of the children's eyesight is given to school teachers;

(3) Whether the teachers instruct the children in the general care of eyesight;

(4) What regulations (if any) have been adopted for the selection of school-books and

atlases (including limits of price, size of type, character of illustrations, weight, &c.), wall maps, charts, and diagrams;

(5) Whether any definite principles or rules have been laid down by or for those who select school-books for the Authority.

Replies were received from sixty Authorities, to whom and their officers the Committee is much indebted for the information supplied.

Under the system of medical inspection now general in public elementary schools, in accordance with the day-school code, the eyesight of children of school age is tested at least twice during their school life, the test being made, with few exceptions, by means of the well known test-cards. A few Authorities in both counties and county boroughs go further, and employ a competent oculist, either part or full time, his duty being to examine special cases and prescribe spectacles or recommend that medical or operative treatment be obtained. Some Authorities have arrangements under which spectacles according to the prescription of their oculist are supplied to the children at cost price, which is comparatively low by reason of special contracts. Arrangements are also made for free provision of spectacles in case of need, frequently with the aid of voluntary associations.

The school medical officers and ophthalmic surgeons on the occasion of their visits give advice to the teachers concerning the treatment of children with defective sight. With one or two important exceptions, however, it would seem that instruction concerning proper and improper use of the eyes in school-work has not been given to teachers. The Committee is pleased to report that, under the new regulations for the training of teachers, hygiene, including testing of eyesight, is now a

compulsory subject for the Board of Education examination of training-college students.

We learn that it is not customary for teachers to give the children special instruction concerning the care of their eyes. It is stated in several instances that teaching of this kind is given incidentally in the course of the lessons on hygiene which form part of the school curriculum; but nothing more is done, and what is done amounts to very little.

Speaking generally, no definite principles or rules as to printing and other conditions of legibility have been adopted in the selection of school-books, atlases, diagrams, &c. Two or three Authorities, when drawing up their book-lists, have given considerable attention to their possible effects on eyesight, but without formulating any definite rules. Several state that the committee or officers responsible for the supervision of the book-supply pay attention to the type, paper, &c.; several, on the other hand, inform us that the selection of books, &c., is left to the teachers.

Summarising the evidence generally, it may be said that whilst effective arrangements for the detection of existing defects in the eyesight of elementary school children are general and arrangements for the supply of proper spectacles at cheap rates are not uncommon, practically no systematic attention is given to the influence of school-books upon eyesight.

The replies lead us to believe that the report of the Committee will have attention from Local Education Authorities.

Report of the Oculist Sub-Committee.

The eye of the child is a growing eye. It is immature both in structure and in function. At

birth the eye has a volume equal to about half that of the full-grown eye; the materials of which it is built are comparatively soft and yielding; the functional power of the visual apparatus is merely a perception of light. By growth and development, rapid at first, slower later on, the eye tends progressively to acquire the dimensions and the powers of the normal completed organ.

Nutrition by healthy blood, and the natural stimulus of voluntary use, are essential to this process. We know by experience that in early infancy disease may arrest the growth of the eye, and that suspension of use, as when a serious ophthalmia prevents an infant for many weeks from attempting to use its eyes, may check functional development to an extent which cannot afterwards be made good. On the other hand, excessive efforts, due to unnatural demands on the eyesight, are apt to be injurious in the opposite direction. Unfortunately there is evidence to show that the demand made on the eyesight of school children is not infrequently excessive.

At the age when school life begins the visual apparatus is still immature. The orbits, the eyes themselves, and the muscles and nerves which move them, have still to increase considerably in size. The various brain-structures concerned in vision have not only to grow but to become more complex. The intricate co-ordinating mechanism which later will enable the eyes, brain, and hand to work together with minute precision is awaiting development by training. The refraction of the eyes is not yet fixed. It is usually more or less hypermetropic, with a tendency to change in the direction of normal sight; in other words, it has not reached the ideal condition in which the eyes see distant objects without accommodative effort, but is tend-

ing towards it. In short, the whole visual apparatus is still unfinished, and is therefore more liable than at a later age to injury by over-use.

Over-use of the eyes is chiefly to be feared in such occupations as reading, writing, and sewing, not in viewing distant objects. During near work the head is usually bent forward, and the blood-vessels of the eyes tend to become fuller; the focus of the eyes is shortened by a muscular effort which alters the form of the crystalline lens; the visual axes, which in distant vision are nearly parallel, are held in a position of convergence, and if the work be reading, they are also moved continuously from side to side. It is near work, therefore, that makes the greatest demand upon the eyes, and the nearer the work the greater the strain. Moreover it is chiefly in near work that continuous mental effort is required.

Children who do too much close eye-work suffer in various ways. Some simply from fatigue, showing itself by inattention, mental weariness, temporary dimness of sight, or aching of the eyes and head. Some from congestion of the eyes, as shown by redness, watering, and frequent blinking. A certain number, in circumstances which predispose them to the disorder, develop strabismus, or squint. Some others—and these cases are perhaps the most important of all—develop progressive myopia.

Myopia, or short sight, commonly depends on undue elongation of the eyeball. It is never, or hardly ever, present at birth. It is rare at five years of age. It usually begins during school life, and increases more or less from year to year during the period of growth. It sometimes continues to increase after growth is completed. It is not necessarily, or always, associated with over-use of

the eyes, either in school or elsewhere, for we see it arise after illness, we meet with it in illiterates, and we know that the predisposition to it is strongly hereditary. But it is everywhere most frequent among the most studious, and there is a mass of evidence to show that it depends very largely, both in its origin and in its progress, on over-use of the eyes in near work.

A moderate myopia which does not increase may be regarded as an innocent, though somewhat inconvenient, over-development of the eye. A high myopia usually involves serious stretching and thinning of the coats of the eye, and a liability to further trouble. A high myopia in a child is a very grave condition, for further deterioration always follows. In connection with myopia alone, to say nothing of other eye defects, the question of school-work in relation to eyesight deserves more attention than it has hitherto received.

The subject has many sides: the lighting of school-rooms, the arrangement of the desks, the design and proportion of individual desks, the attitudes of the scholars, the amount of work required, are all factors of importance; but they cannot be considered here. Our present effort is directed to the standardising of school-books, a very important step in the desired direction.

Small print leads the young scholar to look too closely at his book. He is not yet familiar with the forms of the words, and his attention is not easily secured unless he has retinal images larger than those which satisfy the trained reader. To obtain these larger images he brings the book too near to his eyes, or his eyes too near the book, and this, for the reasons already given, is apt to be injurious. Hence the importance of establishing certain standards of legibility for school-books,

having regard to the ages of the scholars who are required to use them, and of employing only such books as reach these standards.

The importance of the matter becomes still more evident when we remember that, according to recent medical inspection, at least 10 per cent. of the children in our elementary schools have serious defects of vision, and about 20 per cent. errors of refraction, and see less easily and clearly, even when provided with proper glasses, than do normal-sighted children.

At what age should children begin to read from books? From the hygienic point of view the later the better, and there is reason to believe that little, if anything, is lost educationally by postponing the use of books in school until the age of seven at earliest. Beginners may learn to read from wall-charts; and in the general instruction of young children, teaching by word of mouth, with the help of black-boards, large-printed wall-sheets, pictures, and other objects which are easily seen at a distance, is preferable from the medical standpoint, for it has the great advantage of involving no strain on the eyes.

Hygienic Requirements with which School-books should conform.

The Committee desires to acknowledge the helpful advice received from Mr. J. H. Mason, Mr. R. J. Davies, Mr. F. J. Hall, Mr. H. Fitzhenry, and Mr. F. Killick in connection with the technical and trade aspects of this section of its report; also to thank Messrs. Caslon & Co., the Chiswick Press, John Haddon & Co., the Imprint Publishing Co., Miller & Richard, Shanks & Sons, Stephenson, Blake & Co., R. H. Stevens & Co., for the loan of specimen books, types, and printing papers.

The factors which have been taken into consideration are: (1) The nature of the psychological process involved in reading; (2) the quality of the workmanship employed in book-production; (3) the quality of the paper on which text and illustrations are printed; (3a) the mode of binding books; (4) the character of the illustrations and the process employed for their reproduction; (5) the colour and quality of the ink used in printing the text; (6) the mode of printing; (7) the character of the type; (8) the size of the type faces and their vertical and horizontal separation; (9) the length of the lines; (10 to 18) particular requirements of special subjects.

1. *The psychology of the reading process.*—The special consideration to be here noted is that the printing should be such as will facilitate the main aim of reading—viz. the getting of the meaning of what is read. The trained reader generally recognises whole words and phrases at a glance. It is therefore important that the process of beginners should be made as easy as possible towards the recognition of word-wholes and phrase-wholes by the use of type suitable in character and judiciously spaced. The best type for isolated letters is not necessarily the best for word-wholes, and attention must be given to the comparative legibility of letters as seen in context.

2. *Workmanship.*—It frequently happens that much of the good effect of well-selected type, paper, &c., is neutralised by inefficient workmanship. In all the recommendations which follow, good workmanship will be assumed.

3. *Paper.*—The paper should be without gloss. Glazed paper is trying to the eyes by reason of reflections which are apt to interfere with binocular

vision. Pure white paper gives the greatest contrast with the ink, and therefore a paper which is white or slightly toned towards cream-colour is to be preferred under average conditions of class-room illumination. A hard-wearing paper of suitable quality should be used, as a soft paper has two defects—(1) it is readily soiled, (2) the surface is easily rubbed off and the detritus is injurious. The surface should be fairly smooth, because a rough-surfaced paper necessitates a heavy impression in order that the unbroken surface of each letter may appear, which impression is liable to cause a still rougher surface on the other side of the sheet. The print of one side must not show through from the other, and the printing must not affect the evenness of the surface of the other side. These rules also apply to illustrations, which afford a good test of the opacity of the paper. Books are occasionally bound and pressed before the ink is dried, and a faint impression of the opposite sheets causes a haze. Copies with this defect should be rejected.

3a. *Mode of binding books.*—Books should be stitched with thread. Books should open flat and should not require the restraint of the hand to keep them so; stabbing or clipping should therefore be avoided. If not flat, the convex surface of the page gives rise to eye-strain. On recent tests of a large number of school-books Mr. Bishop Harman reports that certain small books with very good paper and type could not be passed as satisfactory because they were clipped from side to side with wire staples. The books could not be opened flat; the back margin was lost and sometimes even the print near the back. The excessive handling needed to keep such books open would soon cause the pages to be soiled. Even in the

better samples of wire-stabbed and thread-stabbed work the margin was reduced.

4. *Illustrations* include (1) pictures for young readers, (2) diagrams and sketches, and (3) photographic reproductions involving considerable elaboration of detail. For (1) it is important to recollect that children are only confused by elaborate or complex pictures. Bold, firm treatment of a few objects is appropriate alike to their visual powers and to their understanding. From this point of view line blocks from pen-and-ink drawings are preferable to half-tone blocks from photographs or from wash-drawings. The pictures should be of a good size, and the printed text should not extend in narrow lines at the side. In the case of (2) diagrams, it is important that the lettering should not be too small to be easily read. (3) For the older scholars it is sometimes necessary to provide illustrations exhibiting details with the precision most readily obtainable by photography. For the sake of obtaining effective illustrations by the half-tone method, use is frequently made of highly glazed paper. Whenever this is done it is important that such paper should be used for illustrations only, and not for the text. By the use of recent methods it is possible to secure half-tone prints with good rendering of detail on matt paper. Blurred photographs not only fail to instruct; they tend to injure eyesight.

5. *Ink.*—The ink should be a good black, and it is important to secure a proper, sufficient, and even distribution of it over the whole page. The use of coloured inks for reading matter is strongly to be deprecated, especially the use of more than one colour on a page.

6. *Mode of printing.*—It is important that types should be in true alignment along the base line.

The practice of printing from stereos produces quite satisfactory results, provided that the stereo is carefully made from new or little-worn type. A slight thickening of all the lines results from stereotyping, but this in no way detracts from legibility. Stereos should not be used when they begin to show signs of wear. The ordinary text of school-books which are intended for continuous reading should not be printed in double columns.

7. *Character of type.*[1]—The type should be clean-cut and well-defined. Condensed or compressed type should not be used, as breadth is even more important than height. The contrast between the finer and the heavier strokes should not be great, for hair-strokes are difficult to see. On the other hand, a very heavy-faced type suffers in legibility through diminution of the white inter-spaces, as, for example, when the space in the upper half of the ***e*** is reduced to a white dot. In an ideal type the whites and blacks are well balanced in each letter, and it is easy to discriminate between ***e***, ***c***, and ***o***, between ***i*** and ***l***, and between ***h*** and ***k***; and to recognise ***m***, ***nn***, ***nu***, ***nv***, ***w***, ***in***. The general form of the letters should be broad and square rather than elongated vertically; thus the letter ***o*** should approach the circular shape. Legibility is not increased by adding to the height of a letter without adding to its width. There should be a lateral shoulder on every type so that each letter is distinct. Long serifs should be avoided, and any extension sideways which forms or suggests a continuous line along the top or bottom is detrimental.

The upper half of a word or letter is usually more important for perception than is the lower half, because the upper half of most letters has a more distinctive shape than the lower. In some

[1] For explanation of technical terms, see Appendix.

recent type-faces the designers have accordingly shortened the letters below the line, and lengthened those above—thus the *p* is shortened and the *h* lengthened, at the same time the upper parts of the *r* have been raised. It is too early to pass judgment on the results, and more experiment is desirable.

With reference to the question of 'modern-face' *versus* 'old-face' design for type, the Committee is not prepared to advise the use of either to the exclusion of the other, good and bad varieties of both styles being at present in use. Great contrast between the thick and thin strokes is a serious defect which often appears in 'modern face.' It is claimed for the 'modern face' that the letters are more legible, and it may be conceded that failure to provide the minimum height of the short letters is more frequent in 'old face.' Hence the letters of the 'modern face' are sometimes more legible in the case of sizes below twelve-point. The advocates of the 'old face' contend that the 'modern face' letters remain isolated, whereas the letters of the 'old face' flow more naturally into words; thus the form of the word and its meaning are apprehended smoothly. It is also claimed that the basic design of the 'old face' is of higher æsthetic merit. The Committee insists on the importance of the minimum height and breadth for the small letters (*vide* columns 2 and 3 of the table), and if this be secured leaves the decision between the 'modern face' and 'old face' to individual judgment helped by the criteria provided in various paragraphs of this report.

Italics, being less easy to read than ordinary type of the same size, should be used sparingly.

8. *The size of type-faces and their vertical and horizontal separation.*—The size of the type-face is

the most important factor in the influence of books upon vision. Legibility depends mainly on the height and breadth of the short letters, for the larger the type the further from the eyes can it be read with ease, and it is of the first importance to induce the young reader to keep a sufficient distance between eyes and book. Children under seven years old should be able to lean back in their seats and read from the book propped up on the far side of the desk. (As a rule books should not be too large or heavy to be held in the hand.) The appended typographical table shows the minimum requirements, in the opinion of the Committee, for the various ages given; the dimensions are given in a form which can be understood and utilised by readers unacquainted with the technical terms used by printers.

The sizes and spacing of the type suggested for age eight to nine years may be adopted for older readers.

The column giving the minimum length of the alphabet of the small letters (*i.e.*, not capitals)

Standard Typographical Table.

Age of Reader	Minimum Height of Face of Short Letters	Minimum Length of Alphabet of Small Letters	Minimum Interlinear Space	Maximum No. of Lines per Vertical 100 mm. or 4 inches	Maximum Length or Measure of Line
Under 7 yrs	3 5 mm	96 mm	6·5 mm.	10	——
7 to 8 yrs .	2 5 mm	72 mm.	4·0 mm.	15	100 mm. or 4 in.
8 to 9 yrs .	2 0 mm.	55 mm.	2·9 mm.	20	93 mm. or 3⅝ in.
9 to 12 yrs	1·8 mm.	50 mm	2 4 mm.	22	93 mm. or 3⅝ in.
Over 12 yrs.	1·58 mm. or $\frac{1}{16}$ inch.	47 mm.	2·2 mm.	24	93 mm. or 3⅝ in.

1 inch = 25.4 mm.

Specimens of printed matter conforming with the above table will be found in a Supplement.

affords a measure of the breadth of the types. Strictly speaking, this cannot be measured by the reader of a book. A sufficiently good estimate can be made when it is recollected that there are twenty-six letters in the alphabet, and accordingly a word of thirteen letters should not fall short, to a material extent, of half the lengths stated in the third column. A rough rule may be given thus: The number of letters per running inch or 25 mm. should not on the average exceed—

6 or 7	letters	for readers	under 7	years.
8 or 9	,,	,,	from 7 to 8	,,
11 or 12	,,	,,	,, 8 to 9	,,
13	,,	,,	,, 9 to 12	,,
13 or 14	,,	,,	over 12	,,

By 'interlinear space' is meant the vertical distance between the bottom of a short letter and the top of a short letter in the next line below. This space between the lines should vary in proportion to the size of the type. Too little space is a source of fatigue in reading, for it involves difficulty in passing from the end of a line to the beginning of the line below. Very wide space, on the other hand, has no advantage as regards legibility, and involves waste of paper and undesirable increase in the size of the book. Columns 4 and 5 of the table indicate a suitable proportion.

9. *The length of the line* is important in a school-book intended for continuous reading. Other things being equal, the longer the line the greater the excursions of the eyes and the greater the difficulty in passing from one line to the next. Very short lines, on the other hand, demand too frequent a change of direction in the movement of the eyes. The use of lines longer than the maxima given in the last column of the table is sure to cause fatigue to a considerable proportion of readers.

Approximate uniformity in length is desirable; but not absolute uniformity. It is doubtful whether the power of fairly rapid intelligent reading can be attained without the *unconscious* performance of the swing from near the end of each line to near the beginning of the next. This swing may be compared with the motion of an oarsman's body between the strokes. An occasional slight indentation in the lines helps the reader; but large ones, if frequent, hinder the acquisition of a good habit of swing. Children of eight years old should not have their reading confined to very short paragraphs, as the habit of swing has been found well established in good readers of between nine and eleven years of age. In other words, these readers made the necessary eye-movements without conscious effort and with great regularity.

Unusual separation of letters should be avoided. For beginners, lines should not end in the middle of a word; the whole word should be carried to the next line and not be hyphened. The admission in the table of a four-inch line for the large type is a concession intended to meet the difficulty of securing an even set of the letters in a line of shorter measure.

Good margins are restful to the eye, and are well worth their slight cost. As a rule the margin at the top or 'head' of a page should be less than that at the bottom or 'tail'; less on the inner side or 'back' than on the outer or 'fore-edge.' So many influences, including optical illusions, have to be considered in determining the proportion of margin that it is not thought desirable to propose formulæ for the purpose. It should be considered a defect in a school-book if the width of fore-edge is less than half an inch, or of back-edge less than three-eighths of an inch, at any page of the book.

Particular Requirements of special Subjects:

10. *Bibles, Prayer-books, and Hymn-books.*—It is to be regretted that these books are so frequently printed in type which is injurious on account of its small size. It is desirable that the standard given in the table should not be lowered with respect to these important books, which are frequently used under poor conditions as regards illumination. The fact must be faced that the Bible contains more matter than can be squeezed into a volume of a size which can be handled by children. It is desirable that one or more volumes should be issued, containing those parts of the Bible which are used in schools. When it is considered desirable to place the complete Bible in the hands of older pupils, this should be in parts or fascicules. The public demand for handy Prayer-books has led to the use of compressed type and of thin paper which is liable to show the print through. Children should not read bijou editions of Bible, Prayer-book, or Hymn-book.

10a. *Poetry.*—As it is occasionally impossible to set poetry satisfactorily in type of the size given for under seven years, except on a large page, a height of face not less than 3 mm., with length of alphabet not less than 84 mm. may be allowed in these cases.

11. *Books for Evening Work.*—The unfavourable conditions resulting from artificial illumination and fatigue of the learners make it highly desirable that the rules 'from age twelve' should be maintained for books to be used for home-work or for evening continuation classes.

12. *Exercises, Sets of Examples, and Questions.*—These are important parts of a school-book, and the rules for the printing of them should on no account be less stringent than those applied to

the rest of the book. The same rules should be applied to test-cards. The use of hektographing or other multiplying processes is increasing in schools. Care should be taken to secure clear and legible copies.

13. *The Types for Mathematical Symbols, including those used for Algebra,* should correspond with, or be larger than, the sizes of type recommended for the various ages. It is important that the smaller symbols should not be too fine. For children under twelve years no fractions should be employed less than 4 mm. in height of face; thus in $\frac{3}{4}$ the distance from the top of the 3 to the bottom of the 4 should not be less than 4 mm. For pupils over twelve the minimum face height for fractions should be 3·5 mm. There should be a clear interval between the figures and the separating line. It should be easy to discriminate between the numerals 3, 6, 8 and 9.

14. *Squared Paper.*—Use of squared paper should be restricted to work for which it is really required. If this be done, and paper with rulings not less than one-tenth inch apart be used, there will be little danger to vision. The use of millimetre paper should be restricted to students over fourteen, and it should only be used by them in a good light—on exceptional occasions.

15. *Atlases.*—It does not appear possible to avoid some use in atlases of type which is below the desirable standard of size, and the care which should be exercised by teachers in regard to the children's eyesight needs to be specially emphasised in this connection. Their use should be avoided when the illumination is below normal—the less they are used for home-work the better. Location by reference lines should be taught from the begin-

ning, and children should not be allowed to hunt for a name in an undirected fashion, as they may thus have to read fifty names in finding the one sought. Atlases intended for use by children under nine should have no type smaller than ten-point, with minimum height of 1·6 mm. or one sixteenth inch for the short letters. No school atlas should be printed with type smaller than eight-point, with minimum height of 1·2 mm. for the short letters. The type should be extended; italics should not be used more than is necessary, and should not have fine hair-lines.

It is not necessary that every map should be coloured. (It has already been pointed out that colour decreases legibility.) In the case of beginners, the colour helps the appreciation of area; but for this purpose the colouring should be pale, and few names inserted. For the pourtrayal of relief, the practice of block-shading the contours is better than heavy black hill-shading by hachures. Maps should be duplicated where it is necessary (*e.g.*, Switzerland) to exhibit great variation of contour together with several place-names. In general it is better to multiply maps than to put much detail into one.

If a system of inserting the names of every town of a certain population be adopted, the result is certain to be overcrowding of those portions of the maps which represent highly-populated countries. It would be better to avoid this overcrowding, even at some sacrifice of systematic uniformity. Modern methods in the teaching of geography are reducing the hunting for place-names, and thereby diminishing eye-strain. This advantage will be more general when the supply of orographical maps to public elementary schools

is increased. The reading of Ordnance Survey sheets by the older pupils is not objected to, provided they are used in good daylight.

16. *Music.*—For the tonic sol-fa notation the minimum height of the short letters should be (*a*) for music, 2 mm.; (*b*) for words, 1·5 mm. Staff music is often produced by lithography, in which all gradations of size and shape are possible. Care in printing is needed, so as to secure well-defined stave-lines and tails. Advantage should be taken of the elasticity in the length assigned to different bars in the lithographed music, so as to avoid compression of complicated passages. For beginners music of the size of the 'Giant Note' is recommended. For others, the stave-lines should not be less than 1·75 mm. apart, or the four spaces should measure not less than 7 mm. The ruled paper for music-writing should have lines not less than 2 mm. apart.

17. *Greek.*—Greek type is troublesome to beginners by reason of its unfamiliarity and of the difficulty of synthetising accents and letters into word-wholes. Type which has a line of uniform thickness affords easy discrimination of individual letters, and is legible in mathematical formulæ, even when small sizes are used. The variety of Greek type which employs fine hair-lines should be entirely abandoned. For reading, it is recommended that no type smaller than twelve-point be used for beginners, or eleven-point for experienced readers.

18. *German.*—The older styles of German type are not easily legible, partly on account of the ill-placed hair-lines at the top of the letters. Recent forms of the black letter used in German books are improved in this respect; but since Roman

type is being used largely even for literary works in Germany, the use of the less legible German types may be reduced in our schools with some gain to the security of eyesight.

Conclusion.

The Committee observes in conclusion that:—

(1) The existence of a very serious amount of visual defect among children of school age is established as a result of official inspection. Some portion of this defect is preventable by greater care in the selection of books.

(2) It is desirable that a standard of book-production should be established, and that the publication of books below standard should cease.

(3) It appears possible that the adoption by local education authorities of a common standard would render unprofitable the publication of books which failed to reach such standard.

(4) It is hoped that this report may assist the responsible authorities in the work of determining the standard of book-production requisite for the protection of the eyesight of children so far as it is influenced by the books which the children are compelled to read in school.

APPENDIX.

Notes on Technical Terms used in this Report.

Type-body, type-face, lateral shoulder, large-face.—The letters are cast on a 'type-body'; the part of the type which actually leaves its impress is the 'face.' When the face is nearly as large as the body will carry, the type is 'large face.' The space on the upper surface of the body on each side of the face is the lateral 'shoulder.' All one reads is the impress of the faces of the type.

Serif.—A type in which each letter had only its bare necessary features would be 'without serif,' the serifs being the terminals of the letters. If of proper design, the serifs guide the eye from letter to letter and give a balanced effect. In some styles the serifs take the form of purposeless ornament, which is undesirable in books which are intended for continuous reading.

In *condensed* or *compressed* type the bodies are narrow, so that the letters are narrow and close together. Column 3 of the typographical table excludes such type.

Old face and *modern face* refer to styles of type. In the specimens in the Supplement the faults of the more extreme varieties of each have been avoided.

Heavy type, heavy fractions refer to type of which the lines are thick.

Point is a unit of measurement. Unfortunately manufacturers do not agree precisely as to the size of 'point' which they use. Approximately one point = 1/72 of an inch. Thus an eighteen-point type has a body one-quarter inch high. The face may be of any size smaller than the body.

Solid and leaded.—If the types of consecutive lines are set with no vertical interval between the bodies, the type is 'solid.' When there is a vertical interval, say of a thirty-sixth of an inch, the type is 'two-point leaded.' A large face type of ten-point body with two-point leading will produce about the same vertical space between the short letters as a small-face type of twelve-point body printed solid.

An *indentation* occurs in a line where the print does not extend to the same length as in neighbouring lines, *e.g.*, the first line of this paragraph.

SUPPLEMENT

SPECIMENS OF TYPE.

The Committee draws attention to the fact that there is considerable variation in the size of the faces of the various types coming under the same rating in point body, or bearing the same trade description. The following specimens are inserted for the purpose of illustrating the dimensional rules proposed by the Committee in the Standard Table (p. 281). The Committee does not undertake to recommend these or other individual designs of type.

For the purpose of testing books reference should be made to the Standard Table, as in several instances the specimens exceed the *minimum* requirements.

No. 1.

UNDER SEVEN.

This type may be used for books to be read by children under seven years. The letters are larger than the minimum in the typographical table. Printed from type known as Thirty Point Old Face.

No. 2.

UNDER SEVEN.

This type may be used for books to be read by children under seven. The letters are larger than the minimum given in the typographical table. Printed from 24 Point Old Style.

No. 3.

UNDER SEVEN.

This type may be used for books to be read by children under seven. The letters are larger than the minimum given in the typographical table. Printed from 24 Point Old Style Antique.

No. 4. AGE SEVEN TO EIGHT

This type may be used for books to be read by children from seven to eight years old. The letters are larger than the minimum given in the typographical table. Printed from Eighteen Point Old Style Antique.

No. 5.* AGE SEVEN TO EIGHT

This type may be used for books to be read by children from seven to eight years old. The letters are larger than the minimum given in a typographical table. Printed from Eighteen Point Old Style, with 2 point Leading.

No. 6. AGE SEVEN TO EIGHT

This type may be used for books to be read by children from seven to eight years old. The letters are slightly larger than the minimum given in the typographical table. Printed from Old Style Great Primer with 3 point Leading.

No. 7.* AGE EIGHT TO NINE

This type is suitable in size for books to be read by children from eight to nine years old. The size of the letters is slightly larger than the smallest given in the typographical table. Printed from Fourteen Point Old Style with 2 point Leading.

No. 8. AGE EIGHT TO NINE.

This type is suitable in size for books to be read by children from eight to nine years old. The size of the letters is slightly larger than the smallest given in the typographical table. Printed from Twelve Point Modern, with 2 point Leading.

No. 8.* AGE EIGHT TO NINE.

This type is suitable in size for books to be read by children from eight to nine years old. The size of the letters is slightly larger than the smallest given in the typographical table. Printed from Twelve Point Antique Old Style with 3 point Leading.

No. 9.* AGE EIGHT TO NINE.

This type is suitable in size for books to be read by children from eight to nine years old. The size of the letters is slightly larger than the smallest given in the typographical table. Printed from Twelve Point Old Style Antique, No. 7, with 2 point Leading.

No. 10. AGE NINE TO TWELVE.

This type is suitable in size for books intended for readers over nine years old. The size of the letters is slightly larger than the smallest given in the typographical table. Printed from Eleven Point Modern, with 2 point Leading

No. 11. AGE NINE TO TWELVE.

This type is suitable in size for books intended for readers over nine years old. The size of the letters is equal to the minimum given in the typographical table. Printed from 12 Point Old Style, with 1 Point leading.

No. 12. AGE NINE TO TWELVE.

This type is suitable in size for books intended for readers over nine years old. The size of the letters is equal to the minimum given in the typographical table. Printed from 12 Point Old, with 1 Point leading.

No. 13. OVER TWELVE.

This type is suitable in size for books intended for practised readers over twelve years old. The size of the letters is in conformity with the smallest dimensions given in the typographical table. Printed from Ten Point Modern, with 2 point Leading.

No. 14. OVER TWELVE.

This type is suitable in size for books intended for practised readers over twelve years old. The size of the letters is in conformity with the dimensions given in the typographical table. Printed from 11 Point Old Style, with 1 Point leading.

No. 15.* OVER TWELVE.

This type is suitable in size for books intended for practised readers over twelve years old. The size of the letters is in conformity with the smallest dimensions given in the typographical table. Printed from Ten point Antique Old Style, with 2 point Leading.

No. 16.* OVER TWELVE.

This type is suitable in size for books intended for practised readers over twelve years old. The size of the letters is in agreement with the requirements specified in the typographical table. Printed from Ten Point Old Style Antique, No. 7, with 2 Point Leading.

12 POINT GREEK.

ΔΙΟΔΕΥΣΑΝΤΕΣ δὲ τὴν Ἀμφίπολιν καὶ Ἀπολλωνίαν, ἦλθον εἰς Θεσσαλονίκην, ὅπου ἦν ἡ συναγωγὴ τῶν Ἰουδαίων, κατὰ δὲ τὸ εἰωθὸς τῷ Παύλῳ εἰσῆλθε πρός,

TONIC SOL-FA MUSIC

(The smallest size suitable for school use)

```
d  :-  :-  |d   :-  :d   |d  :-  :s,  |f  :-  :m   |r  :-  :m   |r   :-  :-
Sleep,      gen  -   tle  babe,  your pret  -  ty   eye -  lids  clos    -
l, :-  :-  |la, :-  :la, |s, :-  :m,  |l, :-  :s,  |f, :-  :s,  |f,  :-  :-
ma :-  :-  |ma  :-  :ma  |m  :-  :d   |d  :-  :d   |d  :-  :d   |t,  :l, :t,
Sleep,      gen  -   tle  babe,  your pret  -  ty   eye -  lids  clos    -
f, :-  :-  |fe, :-  :fe, |s, :-  :s,  |s, :-  :s,  |s, :-  :s,  |s,  :-  :-

                          p
d  :-  :-  |-   :   :    |s  :-  :-   |m  :-  :d   |l, :   :    |t,  :-  :
ing,                      Soft         sleeps  the  moon   -     beam
m, :-  :-  |-   :   :    |d  :-  :-   |s, :-  :m,  |f, :-  :-   |f,  :-  :-
d  :-  :-  |-   :   :    |m  :-  :-   |d  :-  :s,  |r  :-  :-   |s,  :-  :-
ing,                 p    Soft         sleeps  the  moon   -     beam
d, :-  :l, |s,  :   :r'  |d, :-  :-   |-  :-  :-   |-  :-  :-   |-   :-  :
      Sleep on      till  day,
```

The Curricula and Educational Organisation of Industrial and Poor-Law Schools.—Report of the Committee, consisting of Mr. W. D. EGGAR (*Chairman*), Mrs. W. N. SHAW (*Secretary*), Professor R. A. GREGORY, Mr. J. L. HOLLAND, Dr. C. W. KIMMINS, *and* Mr. J. G. LEGGE, *appointed to inquire thereinto, with special reference to Day Industrial Schools.*

IN furtherance of the Committee's recommendation copies of their Report of 1912 were sent (by order of the Sectional Committee) to the Board of Education, the Home Office, and the Local Government Board. The Committee were reappointed to watch for provision being made for 'adequate reports upon all educational work and training either to central or local authorities.' In the event of no such provision being made the Committee were authorised to arrange for a discussion to elicit public opinion on the matter.

In a speech in the House of Commons on July 22 (reported in 'The Times,' July 23) the President of the Board of Education asked: 'Would the House believe him when he said that it was not possible for him, as Minister of Education, to say how many Secondary Schools there were in this country, or what they were doing? There might be 10,000 or 15,000; he could not say *because he had not the right to ask.*' The President might have included in this question Elementary as well as Secondary Schools.

He went on: 'They told him that in the County of Middlesex there were perhaps several hundreds of schools outside the purview of the Board of Education altogether.' The British Association Report of last year shows that this is undoubtedly true of many institutional schools throughout the country. To quote the President further, 'The State, having made education compulsory, ought, however, to be in a position to give parents some guarantee that the education which their children received was not positively harmful to their minds or bodies.' To meet this state of things the Government would propose next session 'that there should be power to make a comprehensive survey of educational institutions of every kind.' 'The Board of Education would take power to decide what was and what was not education.'

Any survey of schools presupposes a knowledge of the existence of the schools. It would not appear possible to obtain this knowledge without the co-operation of the schools themselves. There are at present no lists of schools which are complete for either elementary or secondary education. What is required is power to obtain complete lists.

The Committee have therefore arranged for a discussion on the 'compulsory registration of all schools, public or private, and of all institutions giving instruction, technical or general, with the qualifications of the teachers.'

The Committee have considered the question of registration with a local or central authority. The Board of Education appears to be in the first instance the appropriate authority. As a Government department dealing expressly with educational organisation and requirements for the whole country it would appear that the primary need of such a

department is complete knowledge of existing educational facilities, and the Committee therefore desire to ascertain the views of representatives of various classes of schools on the question.

In the discussion it is expected that papers will be read by the Right Reverend Bishop Welldon, Dean of Manchester, the Right Reverend Bishop McIntyre, Roman Catholic Bishop of Birmingham, and Mrs. Sophie Bryant, D.Sc.

The discussion will be continued by speakers representing girls' private boarding-schools, waifs and strays schools, and others.

Mental and Physical Factors involved in Education.—Report of the Committee, consisting of Professor J. J. FINDLAY (*Chairman*), Professor J. A. GREEN (*Secretary*), Professor J. ADAMS, Dr. G. A. AUDEN, Sir EDWARD BRABROOK, Dr. W. BROWN, Professor E. P. CULVERWELL, Mr. G. F. DANIELL, Miss B. FOXLEY, Professor R. A. GREGORY, Dr. C. W. KIMMINS, Professor McDOUGALL, Drs. C. S. MYERS, T. P. NUNN, W. H. R. RIVERS, *and* F. C. SHRUBSALL, Mr. H. BOMPAS SMITH, Professor C. SPEARMAN, Mr. A. E. TWENTYMAN, *and* Dr. F. WARNER, *appointed to inquire into and report upon the methods and results of research into the Mental and Physical Factors involved in Education.*

THE Committee has been concerned with the problem of the Psychology of Spelling with a view to the establishment of sound methods of teaching. In pursuit of this end researches were instituted under the guidance of Dr. Myers at Cambridge and Professor Findlay at Manchester. The reports of these researches are given below. The conclusions they embody have not, however, been accepted by the Committee. They are submitted for discussion with the further hope of stimulating additional research.

The thanks of the Committee are due to Miss Fairhurst and Miss Suddards for the work they so kindly undertook. The Committee desires to be reappointed.

1. *Psychological Analysis and Educational Method in Spelling. By* Miss SUSIE S. FAIRHURST.

Spelling, as the reproduction of the constituent parts of a word-whole, in speech or writing, involves a mechanism somewhat different from that of reading, which is recognition of the word-whole. The desideratum of teaching method is that it should involve the least possible expenditure of time and energy in the production of efficiency in spelling. A study of the actual processes involved, in children and adults, is obviously of first importance.

In the total word-complex there are the visual and writing-motor elements forming the written symbol, and the auditory and speech-motor elements of the spoken symbol. The visual and auditory

elements may be either perception or imagery; the motor elements either actual movement or imagery. The writing-motor adjustment is less highly specialised, more artificial, and more lately acquired than the motor processes of speech. It is probable that its imagery does not pass over so readily or so definitely into actual movement. The impulse to image or actually to experience the writing movement on hearing a word is much more controllable than the tendency to articulate on seeing it. The visual form of each letter carries a qualification due to the tactual and muscular experiences of writing it; but those experiences are not nearly so important for the comprehension of the visual form of a new word as are the speech-motor elements. They are probably more important with children than with adults. Writing movements do not appear to act as an independent medium of memory, as the speech movements may do; they rarely enter as a conscious factor into recall, and, when present, are so as a qualification of the visual memory. The intrinsic value of the writing memory appears greater than it strictly is by virtue of the extra aids it affords to visualism, to attention, and to the fusion of the visual and auditory elements.

Articulation of syllables is usually introduced into any method of learning. The visual form does not become a 'word' until it is pronounced, either aloud or internally. The tendency to pronounce on seeing the word is almost universally irresistible and essential to learning, whatever the imaginal type of the observer. Anthropological considerations throw some light on this fact—spoken language precedes written.

The *unit* of spelling is usually the syllable—the syllable finds direct expression as one whole, even in spelling by speech. And the syllable is primarily a speech-unit; the letters are grouped by sound-synthesis, the visual form often showing syllabic grouping in correspondence. There is visual synthesis of the general form of the word, as a visual picture, apart from its sound-value, but the synthesis of syllabic grouping is determined by and follows on articulation. With a perfectly familiar word, the articulatory syllable simply 'is' the visual form—the fusion is complete. As regards the correspondence of visual and auditory constituents, the English language is in a peculiar position. The visual word-whole contains its parts, the letters unchanged. The auditory-motor whole is a very different thing from the sum-total of the sound values of the letters (apart from letter-names); some of them are not represented at all, and many are quite changed in value. The auditory constituents of a word are strictly not the letters, but phonetic units. A complicated and highly variable system of correspondences between the spoken and written letters thus occurs. This increases the strain on mechanical memory—a separate memory for almost every word being necessary.

Articulation of the letters is thus no direct aid to the spelling memory and a wasteful method of learning. Drill of some form is, however, essential to spelling efficiency, since the spelling process is in the nature of a habit, and efficiency means a habit so fixed as to be almost unconscious. Articulation of the syllables simultaneously with

the writing of the word is probably the best method of learning—it introduces every essential element, visual, auditory, and motor; by producing the visual elements in succession it aids the exact analysis of the speech-whole, it helps the synthesis of the visual elements in accordance with the articulatory units, and therefore the fusion of the written and spoken symbols.

The experiments on which these conclusions are based will be described at the meeting.

2. *An Investigation into Spelling at the Fielden Demonstration School. By* Miss Ida Suddards *(in collaboration with other members of the staff,* Miss Mitchell *and* Miss Matthias).

Part 1.—*The Problem.*

(*a*) Spelling is the reproduction from memory of certain arrangements of symbols to which convention has attached definite meaning for the common purpose of written intercourse. The good speller normally achieves success through constant practice in reading and writing, whereby correct mental images, visual, auditory, and motor, are obtained largely on the margin of attention. Practice in the correct writing of words implies:

(1) Imitation, by means of which certain memory images develop and the required habit is gradually formed;

(2) Reproduction by means of these memory images—notably motor images.

The scholar reaches the end in view when the written symbol is produced automatically in the conventional spelling.

(*b*) It is only necessary to be able to spell such words as we need to write. The smaller the vocabulary the smaller the chances of bad spelling. Many schools, especially some elementary schools, produce a great number of people who never spell badly because they use so few words. The sacrifice of ideas to formalism necessarily restricts growth of vocabulary, and scholars passing through such schools spell correctly because of the limited number of words they have the opportunity of spelling incorrectly; but these are badly educated people. Modern culture implies a wide experience in reading and writing; hence it follows that scholars must be allowed scope for reading and writing freely.

(*c*) But here is the crucial point—the greater the opportunities for enlargement of experience the more pronounced the spelling difficulty becomes. Of the child's three vocabularies, (1) speaking, (2) reading, (3) writing, the growth of (1) and (2) far outstrips (3), *and in the attempt at a wider and more complete expression the habit of bad spelling is formed. It is this differentiation of rate in the acquirement of the three vocabularies which is at bottom the cause of bad spelling.*

(*d*) To meet this difficulty some schools place undue emphasis on spelling. The scholars spend time and effort on spelling lists and rules as a separate branch of study. Any such attempt at basing spelling on conscious processes fails in that it fixes attention on the

mechanism of expression rather than on the thought to be expressed; to have to think how to spell a word hinders expression. The problem then is to insure the same standard of accuracy, but by means which will not hinder development or waste time.

PART II.—*Investigation of this Problem with Scholars ages* 8 *to* 10.

(*a*) By the tests referred to in the paper the following points were noted:—

1. The highest standard of accuracy was reached by the eight year olds in Class II. who have no free written composition. The subject matter of their writing is given orally by the scholars, written on the blackboard by the teacher and copied by the scholars into their books. They see and write only the correct forms of words, and their written vocabulary is thus under the control of the teacher.

2. Class III. (nine year olds) gave a higher percentage of error. In this class free composition is first begun, the teacher loses control of the written vocabulary, and the spelling disease begins to show itself.

3. In Class IV. the speaking and reading vocabularies increase still more rapidly, the teacher has still less control than in Class III., and inaccurate spelling was shown to be on the increase.

(*b*) As a result of this diagnosis the following reforms are being instituted:—

1. It is clearly better to spend time in the forming of accurate spelling habits at the beginning than in the correction of wrong habits later. In the early stages scholars may be prevented from spelling incorrectly by never giving them the opportunity of doing so; hence we now delay 'free' written composition so as to keep the scholars' written vocabulary within the control of the teacher.

2. The transition to free written composition is made gradually with strict oversight from the teacher. The scholars use small dictionaries and are constantly reminded of the need for correct spelling in any 'free' writing which they undertake.

3. In spite of these precautions some errors still occur. From the result of a recent investigation by Mr. Stanley Wyatt at the F.D.S. into methods of treating errors, the following procedure has been adopted for the correcting of these:—

The misspelt words are to be actually obliterated and practice given in the writing of the correct symbols—*i.e.*, the right form is brought to the focus of attention. Each scholar keeps his own note book, where such words are entered.

(*c*) In every class there are one or two scholars for whom the ordinary class teaching is not sufficient. For these spelling is made more of an independent study, and special methods are devised to meet the needs of individual cases, taking time from other pursuits. Such cases, however, are not permitted to stop the normal progress of the class as a whole.

Report of the Committee, consisting of Sir HENRY MIERS (*Chairman*), Professor MARCUS HARTOG (*Secretary*), Miss L. J. CLARKE, Miss B. FOXLEY, Professor H. BOMPAS SMITH, *and* Principal GRIFFITHS, *appointed to inquire into and report on the number, distribution, and respective values of Scholarships, Exhibitions, and Bursaries held by University Students during their undergraduate course, and on funds private and open available for their augmentation.*

YOUR Committee sent out early in the spring a Questionary to the Heads of all the Universities and University Colleges in the British Isles (omitting professional and technical schools). Their answers, arranged and somewhat abridged, will be found in Appendix I. We have omitted much valuable information dealing with benefactions for post-graduate and research study, and limited ourselves to answers dealing with the courses for the primary degree. Appendix II., modified from the evidence before the Royal Commission on the Civil Service, shows in order of value of total emoluments the number of beneficiaries entering the Universities of Oxford and Cambridge respectively.

The Committee desire to express their warm thanks to those who by their willing answers have enabled them to present so much valuable information to the British Association, and suggest the desirability of their reappointment.

APPENDIX I.

QUESTIONARY AND ANSWERS.

University College, Cork: March 11, 1913.

DEAR ——

On behalf of the above Committee I write to ask if you will very kindly furnish me with information in regard to the following questions:—

I. The number, duration and respective values of Scholarships, Exhibitions, and Bursaries in your College?

II. Whether two or more such benefactions are tenable together?

III. Whether any limit is imposed on the maximum annual income derived from endowments of all kinds by a single beneficiary?

IV. Have you at your disposal any funds (*a*) of permanent endowment; or (*b*) of private benefaction to supplement Scholarships, &c., for the complete maintenance of students of exceptional promise?

V. (*a*) Have cases occurred in which successful candidates have been obliged to decline Scholarships, &c., on the ground of inadequate personal means?

(*b*) Have any deserving beneficiaries retired during their course through lack of adequate means?

(*c*) Have such resignations been met by help from or through the College; and if so in what way?

VI. Will you very kindly add any further suggestions or information bearing on this matter?

I am, dear ——

Faithfully yours,

MARCUS HARTOG

(Secretary to the Committee).

ANSWERS RECEIVED.

BALLIOL COLLEGE, OXFORD.

I. Annual open, 4 minor Exhibitions of 40*l.*; 3 Exhibitions of 70*l.*; 7 Scholarships of 80*l.* Annual close, 1 Exhibition of 180*l.*; 1 Scholarship of 60*l.* Every fourth year, 1 close Exhibition of 40*l.*; 1 Scottish Exhibition of 120*l.*

The above are generally tenable for the full Undergraduate course (four years). Annual; 1 Exhibition of 100*l.* for Senior Undergraduates of the College for two years.

II. No; except last Exhibition of 100*l.*, and a minor Exhibition of 40*l.* is tenable with close Exhibition of 60*l.* when the candidate has taken a high place in the Open School Examination.

III. No limit. Most scholars and some commoners hold subventions from School, County Council or City Companies, and a few gain University Scholarships.

IV. A fund of 150*l.* per annum charged on College revenues, supplemented by private benefactions, amounting to an average of 330*l.* for the last ten years. This is used to help commoners as well as scholars who need a supplement. Exceptional promise would be an additional inducement for grants, not a necessary condition.

V. (*a*) and (*b*) Not aware of such refusals for the last twenty years, but they may have occurred earlier. After the death of two predecessors it became known that they had helped privately.

(*c*) The fund under (IV.) would be applicable. Cases where a man has for family reasons to emigrate or begin earning money without completing his University career cannot of course be met.

VI. 'Given a man of health and ability sufficient to be successful in open competition, and of sufficient previous education, I believe that there is nothing to deter a poor man from a successful Oxford career. If there is any obstacle it must be found on the "lower rungs of the ladder." I am told that opportunities differ considerably in different parts of the country.'

Form sent to the father or guardian of scholars elect at Balliol College, Oxford:—

DEAR SIR, Balliol College, Oxford.

Under a system by which Scholarships and Exhibitions are filled by open competition, it will inevitably happen that they are sometimes gained by those who are not in need of the emoluments attached to them. You will have seen that this possibility is anticipated in the notice relating to Scholarships and the conditions of their tenure issued before the Scholarship Examination.

If this is the case with Mr.   who has been elected to a   at this College and you think it proper that he should surrender the whole or any part of the emoluments to which he is entitled while retaining the status and other privileges of a   , I have to inform you that effect will be given by the College to your wishes as to the application of such emoluments. Should you express no such wishes as to the application, any money which he may surrender now, or which at any future time he may feel himself to be in a position to surrender or repay, will be paid into a Fund established in the College for the assistance of those who require assistance to avail themselves of the advantages of a University education. Any such renunciation of emoluments will be treated by the College as confidential, and those receiving the help you give will only know that it comes to them through a College Fund.

I enclose a memorandum which will inform you as to College expenses.

Will you kindly let me know what are your wishes in this matter?

I am, Sir,
Yours faithfully,

Master of Balliol College.

BRASENOSE COLLEGE, OXFORD.

I. (*a*) Open:—13 Scholarships of 100*l.*; 4 (usually, number variable) of 80*l.*; unfixed number of Exhibitions of 70*l.* (*b*) Restricted:—4 Scholarships of 80*l.*; variable number of Scholarships of 70*l.*; 2 Exhibitions of 80*l.*; 3 Exhibitions of 40*l.*

II. Blank.

III. No limit.

IV. No funds specifically set aside, but men whose College emoluments are

supplemented by grants from school funds, &c., can sometimes support themselves completely during their career.

V. (*a*) and (*b*) No.

(*c*) ——

VI. Scholarship Regulations contain proviso: 'The holder of any Scholarship to which no pecuniary restriction is attached will be allowed to retain the status of a scholar without receiving the emoluments, should he express a wish to that effect.'

Christ Church, Oxford.

I. Open: 6 Scholarships of 80*l.*; 3 Exhibitions of about 85*l.* (money and allowances). Close: 3 Scholarships of 80*l.* All tenable for two years and renewable for two more by the Governing Body, and ultimately for a fifth in satisfactory circumstances.

II. No.

III. No limit for Scholarships. Candidates for Exhibitions must satisfy the Dean that they are incapable of coming to the University without financial assistance.

IV. (*a*) Grants may be made from College Funds, not amounting in all to over 400*l.* in any one year, to scholars or commoners who need assistance. Such grants are in practice made for one year only, but are renewable.

(*b*) There is a Poor Scholars' Fund which depends almost entirely on private benefactions administered by the Dean.

V. (*a*) and (*b*) I know of none.

(*c*) Financial difficulties have been met under IV.

VI. The statutes make a similar provision to Brasenose College.

Exeter College, Oxford.

I. 11 Scholarships, open, of not more than 80*l.* and 1 of 100*l.*; 8 close of not less than 60*l.* and 1 or more of not more than 100*l.* (all of which may be opened in default of the preferred class of qualified candidates); 2 Scholarships of 80*l.* for persons intending to take Holy Orders and needing assistance at the University. Various Exhibitions (mostly close), all limited to those needing assistance at the University.

III. None by Statute, but by College policy.

IV. No permanent endowment; but a deserving scholar who is poor can be helped by a grant from general College Funds or a special fund.

VI. (*a*) Only Scholarships of less than 80*l.*

(*b*) None.

Hertford College, Oxford.

I. Majority Scholarships, open to Churchmen only, 30 of 100*l.* for five years; 10, varying from 40*l.* to 80*l.*, for four years, besides a number of Exhibitions.

II. Not from College sources.

III. No limit.

IV. No.

V. (*a*) Exhibitions only.

Jesus College, Oxford.

I. Open Scholarships, 12; close Scholarships, 22 of 80*l.* to 100*l.* Exhibitions, several open and several close, of 30*l.* to 60*l.* All granted for two years and renewable on satisfactory industry and good conduct for two more.

II. No, but a grant from the Exhibition fund may be made to a scholar or exhibitioner.

III. No statutable limit, but no grant is made out of the Exhibition Fund except to the really necessitous.

IV. (*a*) The Exhibition Fund.

V. (*a*) Only one case in forty years unable to come up on 60*l.* per annum.

(*b*) No.

(*c*) In extreme cases exceptionally large grants have been made from the Exhibition Fund.

Lincoln College, Oxford.

I. Scholarships, about 17 of 80*l.* or 60*l.*; Exhibitions, about 10 of 40*l.*, or more usually 30*l.*

II. No; but the value of a Scholarship may be increased, or an exhibitioner elected to a Scholarship.

III. No limit; the College is not always aware what other benefactions are held.

IV. (*a*) There is a small fund applicable.

(*b*) Occasionally private benefactions are forthcoming, or the College may grant remission of fees or other charges to deserving students.

V. (*a*) Yes, occasionally.

(*b*) and (*c*) I cannot recall such cases.

VI. A similar provision to that of Brasenose College.

MAGDALEN COLLEGE, OXFORD.

I. 30 Scholarships and Exhibitions in variable numbers, according to needs and merits of candidate: tenable for not exceeding four years as a rule, in many cases for only three, never exceeding five.

II. No; except in so far as additional grants are made from the Exhibition Fund, independently or in addition to Scholarships.

III. No limit; but we take maximum annual income into account in awarding Exhibitions or grants. There are a certain number of Scholarships and Exhibitions given by the County Councils and by the City Companies, sometimes on the results of examinations, sometimes on recommendation, which are of very material assistance to students.

IV. (*a*) The Exhibition Fund, which could in theory be used for complete maintenance of students of exceptional promise. But practically speaking, it is not so used, as we always expect that the student should enjoy some other benefaction, or that friends should come to his aid.

V. (*a*) I have known of no case.

(*b*) Very seldom.

(*c*) As a rule assistance has been given from the Exhibition Fund, supplemented by donations from private friends.

VI. It not infrequently occurs that successful candidates decline to accept Scholarships in whole or in part because they do not need the whole assistance. I am inclined to think that money given in Scholarships is at present too diffused, and that it is better for County Councils and others to concentrate their resources on a few candidates of marked ability rather than to spread them over a number of weaker candidates who often are not able greatly to profit by an University education.

NEW COLLEGE, OXFORD.

I. 10 or 11 Scholarships of 50*l.* in each year, tenable for two years, renewable for two years, and in exceptional circumstances, for a fifth; 6 Scholarships are restricted in the first instance, but, if the limited candidates do not show sufficient merit, may be thrown open for that competition. About 2 or 3 Exhibitions of 50*l.*, tenable for two or three years, confined to those in need of assistance, not tenable with Scholarships.

II. Tenable with outside Exhibitions (School, County Council, &c.). We have a private Exhibition, usually of the value of 30*l.* a year, given to those men who may be in need of assistance, tenable with a Scholarship.

IV. (*a*) The Exhibition Fund; a loan fund.

(*b*) A small private benefaction.

V. (*a*) I can scarcely remember any such case.

(*b*) I can scarcely remember any deserving candidates who have had to retire during their course for lack of means, though a man who is not succeeding well might be allowed to retire.

PEMBROKE COLLEGE, OXFORD.

I. 34 ranging from 100*l.* downward, chiefly 80*l.*, mostly restricted to schools or localities, tenable during residence for four years.

IV. No.

V. (*a*) and (*b*) Not during my Mastership.

ST. JOHN'S COLLEGE, OXFORD.

I. Open Scholarships, 13 of 80*l.*; close Scholarships, 22 of 100*l.* (besides 4 open to members of the College of 4 terms standing of 80*l.*, and only tenable for one or two years). All open Scholarships and 7 of the close, tenable for four years, which may be increased to five; 15 close Scholarships, tenable for five years.

At present, 7 open Exhibitions of 40*l.* to 70*l.*, tenable as open Scholarships; 5 close Exhibitions of 40*l.* to 80*l.*, tenable as open Scholarships. Variable number (5 at present) restricted to undergraduates of 4 terms, of 20*l.* to 60*l.*

II. Scholarships and Exhibitions not tenable together.

III. No limit.

IV. (*a*) The Exhibition Fund of not less than 600*l.* per annum. It is not usual to grant more than 60*l.* in one year to an individual.

(*b*) A small fund of about 40*l.* in the hands of the President, sometimes augmented by private gifts to 70*l.*, is usually distributed in gifts of about 10*l.* to deserving and needy undergraduates, not necessarily scholars or exhibitioners.

V. (*a*) I cannot recall any.

(*b*) I think not.

(*c*) If such resignations were threatened, the College would certainly intervene in the case of a promising and deserving undergraduate.

VI. I have only to add that this College has for many years past done its best to keep and encourage poor men.

MERTON COLLEGE, OXFORD.

I. 20 Scholarships of 80*l.*; 4 Exhibitions of 80*l.*, plus a limited number (about 2 a year) of 60*l.*, restricted to candidates in need of assistance at the University. All tenable at the outset for two years, renewable for two years if the holder has given satisfaction. A fifth is sometimes sanctioned for special reasons.

II. No.

III. No.

IV. An Exhibition Fund, including an annual subsidy not exceeding 400*l.* from the College, and the emoluments of vacant Scholarships and dividends from two bequests of about 60*l.* a year.

V. (*a*) No resignations. The College gives help from the Exhibition Fund to very poor students who cannot live on their Scholarships. Only latterly the holder of an Exhibition of 80*l.* received an addition of 50*l.* on the grounds of poverty and exceptional promise. But so large a grant is unusual.

WADHAM COLLEGE, OXFORD.

I. 14 Scholarships, 1 of 86*l.*; 13 of 80*l.*, tenable, as a rule, for four years; 14 Exhibitions of 23*l.* to 60*l.*, tenable for four years.

II. No, with four special exceptions.

III. No.

IV. (*a*) A fund of about 50*l.* in the Warden's hands to assist deserving students.

(*b*) Frequently some assistance from private benefaction.

V. (*a*) and (*b*) I have never known of such cases. Sometimes deserving students get their Scholarships or Exhibitions supplemented by private benefaction.

VI. Our scholars almost always come from homes where some help is needed for a boy to come to the University. During my thirty years' experience I cannot recall a single case of a scholar or exhibitioner to whom the money was immaterial, and may also mention that in case of special need or desert help is given for residence during a fifth year. Each such case is decided on its merits.

ALL SOULS' COLLEGE, OXFORD.

I. 4 Bible Clerkships, value consisting in lodging, tuition, and allowances, fully covering board during academical terms, tenable for three years.

II. No.

III. No.

IV. A sum of 150*l.* per annum in aid of non-Collegiate students in cases of need, on the recommendation of the Censor.

V. (*a*) and (*b*) No cases.

QUEEN'S COLLEGE, OXFORD.

I. 4 open and 1 close (which in defect of qualified candidates, is thrown open). Scholarships of 80*l.* awarded annually, tenable primarily for two years, and renewable, if holders are satisfactory, for two years; for special reasons, may be continued for a fifth.

Two Bible Clerkships conferred, as vacancies occur, on deserving persons in need of assistance at the University, of 80*l.* (or 90*l.* if resident in College), on same tenure as Scholarships.

1 J. O. F. Scholarship of 90*l.* every fourth year, restricted to Churchmen, and 4 J. N. F. Scholarships of 100*l.* for five years, awarded as they fall vacant, restricted to Churchmen. *Caet. par.* a candidate who stands in need of pecuniary assistance is to be preferred.

Exhibitions, all close, 4 or 5 of 100*l.*; 1 of 100*l.* for two years, which may be extended to a third and to a fourth year; 1 of 42*l.*; 2 of 68*l.*; 2 of 25*l.*; 1 of 43*l.*; 1 of 6*l.*; 1 of 5*l.* 5*s.*; 1 of 9*l.* Most of these are restricted to poor and deserving students. All may be thrown open on defect of qualified candidates. Close, of 70*l.* for seven years; 2, 40*l.* for four years; 1, 33*l.* for four years; 2, 60*l.* for four years; 1, 62*l.* for students of the College in their twelfth term (theological) for one year, which may be extended to a second; 1 of 50*l.* a year, and a benefaction of 10*l.*

II. No.

III. No. A large proportion of our scholars and exhibitioners receive supplementary Scholarships from their Schools or County Councils or from the City Companies. A good many are completely maintained.

IV. A small Exhibition Fund might very occasionally be available, but it cannot be advertised.

V. (*a*) No.

(*b*) No.

(*c*) Difficulties have frequently been met by aid from the Exhibition Fund.

TRINITY COLLEGE, OXFORD.

I. (*a*) 18 Scholarships of 80*l.*; 8 Exhibitions of 60*l.* to 70*l.*; 4 or more close Studentships of 55*l.* Scholarships and Studentships tenable for four years; Exhibitions for three or four years.

II. No.

III. No.

IV. An Exhibition Fund from which payments can be made to members of the College who need assistance to complete their University course; private benefactions from time to time.

V. (*a*) Very rarely, as candidates usually know the probable expenditure required for a University course.

(*d*) I remember none.

(*c*) The College has not infrequently supplemented Scholarships by grants from the Exhibition Fund and by loans.

VI. A considerable number of members of the University, including many of those who hold College Scholarships, have been awarded University Exhibitions by the Education Authority of the district to which they belong.

KEBLE COLLEGE, OXFORD.

I. Scholarships of 80*l.*, Exhibitions of 50*l.* primarily for two years, though capable of being extended for two more.

II. No.

III. No.

IV. I have 200*l.* a year of permanent endowment that I can use in this way.

V. (*a*) and (*b*) No cases.

LADY MARGARET HALL, OXFORD.

IV. There is a Loan Fund common to all women students in Oxford.

V. (*a*) Yes, occasionally.

SOMERVILLE COLLEGE, OXFORD.

I. Awarded annually, 2 Scholarships of 60*l.* for three years; 1 of 50*l.* for three years (which may be extended for a fourth). Awarded triennially, 2 Scholarships of 50*l.* for three years (with possible extension for a fourth), and one of 40*l.* for three years. A few Exhibitions (1 to 3) of 20*l.* to 30*l.* for three years (with possible extension to a fourth).

Another Scholarship of 50*l.* is awarded without examination annually, usually to extend a three-years' Scholarship to a fourth year.

II. No.

III. No.

IV. (*a*) No permanent endowment.

(*b*) Friends of the College have occasionally supplemented Scholarships privately. There is the Loan Fund (see Lady Margaret Hall, Oxford).

V. (*a*) I don't remember such a case.

(*b*) One case. The scholar was (already) a graduate of another University, and the College thought it best in the scholar's own interest that she should accept a good teaching post offered her and resign the Scholarship.

VI. A scholar or exhibitioner may, for the benefit of others who need assistance, relinquish the whole or part of the emolument, while retaining the title.

St. Hugh's College, Oxford.

I. Annually, 1 Scholarship of 25*l.*; biennially, 2 of 30*l.*, 2 of 40*l.*, all tenable for three years and renewable for a fourth.

II. No.

III. No.

IV. None.

V. (*a*) No.

(*b*) and (*c*) Retirements would have occurred but for help through the College (private Loan Fund) or from the Loan Fund of the Association for the Education of Women in Oxford.

Christ's College, Cambridge.

I. Average number of scholars and exhibitioners in residence, 40. Nominal value, 20*l.* to 80*l.*; but additional grants or reduction of fees, amounting to at most 20*l.*, are sometimes allowed privately in cases of poverty. Except there be distinct evidence of idleness, the Scholarship is retained normally to end of third year, sometimes continued to fourth, and occasionally to fifth year. The total average annual amount of the last six years is 1,800*l.*

II. No two *open* Scholarships or Exhibitions tenable together, but the value of a Scholarship may be increased. A *close* Scholarship, connected with a particular School, may be held with an open Scholarship.

III. No. The amount of a student's income from endowments of all kinds is, however, a factor in fixing the amount of his Scholarship, except in the case of those elected before coming into residence.

IV. No.

V. Candidates for Scholarships awarded before residence has commenced are asked to state the minimum value they are prepared to accept, and if they do not come up to the necessary standard for that value they are not elected. In very rare cases such a candidate has written to say he finds he cannot come into residence on account of his Scholarship not being adequate.

VI. The fund for these benefactions arises partly from trust funds, liable to considerable fluctuations, but chiefly out of the corporate income, the amount payable out of this to the fund being one-quarter of the sum paid in the same year to the Master and Fellows; and this sum again has of later years been supplemented by grants from the Society. Our system has the great advantage of elasticity; the amount and duration of the Scholarship is within certain limits fixed by ourselves to meet the requirements of the special case.

The present system works well. No rich men hold Scholarships, and in nearly every instance the benefaction is necessary to enable the student to come to the University. The cases in which an intellectually deserving candidate fails to obtain a Scholarship are rare indeed; they hardly exist. It is most undesirable to attract by emolument poor men of ordinary ability. . . . The College badly wants funds for advanced students in specialised subjects.

Downing College, Cambridge.

I. 6 Foundation Scholarships at least tenable till graduation standing of 50*l.* to 80*l.*; a varying number of minor Scholarships and Exhibitions, tenable for one year, of 20*l.* to 50*l.*

II. No; but may be tenable with benefactions outside the College.

III. No.

IV. No.

V. (*a*) I can recall no case.

(*b*) and (*c*) Additional aid from the College has prevented any actual retirement.

Jesus College, Cambridge.

I. Entrance Scholarships are limited by Act of Parliament to 80*l.*, and tenable for two years, but are ordinarily renewed and frequently increased in value. Scholarships (except some close Scholarships) are never less than 40*l.* and seldom exceed 80*l.*

II. Trust and open Scholarships may in general be held together, but the total amount of benefaction received by any individual seldom exceeds 80*l.*

III. No limit is imposed. I do not see how it would be possible to do so. But in determining the value of any Scholarship regard is paid to the total income of the

scholar and his parents' means. Generally, this is only possible in the case of scholars already in residence.

IV. No; but privately many scholars (and undergraduates who are not scholars) receive assistance from the College or the Tutor.

V. (*a*) No, by the conditions: 'Candidates are required to state the value (usually minimum) which they are prepared to accept, and are bound to accept any offer of the value they state.'

(*b*) Whether any scholars have *ever* retired for this reason I do not know; there has been no recent instance.

(*c*) The College sometimes gives assistance to scholars and others.

MAGDALENE COLLEGE, CAMBRIDGE.

I. Number variable of Scholarships and Exhibitions. At present 24 in residence, besides 6 Sizars and 4 Subsizars. Scholarships are of 40*l.* to 80*l.*; Exhibitions generally of 30*l.*; tenure of both for two years, after which they may be prolonged and increased if the holders prove of sufficient merit. Sizarships are worth about 34*l.* and Subsizarships consist in the reduction of certain fixed charges, and admission to certain privileges at a given fixed charge.

II. A Scholarship or Exhibition is tenable with a Sizarship or Subsizarship, or with a 'private Exhibition' of 25*l.* (see IV).

III. No.

IV. (1) Trusts amounting to about 120*l.* per annum from which small benefactions are made annually to poor and deserving students.

(2) Ordinands Fund of 50*l.* from which grants of 10*l.* are made to candidates for ordination requiring assistance.

(3) A private Exhibition Fund, providing 12 Exhibitions a year of 25*l.*; but in no case do we provide for the complete maintenance of students.

V. (*a*) Occasionally; but it seldom, if ever, happens that a candidate of real ability is obliged to decline an emolument on such grounds, as they are generally able to get additional help by means of School, or County Council, or City Company Exhibitions.

(*b*) No, not to my knowledge.

PEMBROKE COLLEGE, CAMBRIDGE.

I. Annually offered, 2 Scholarships of 80*l.*; 4 of 60*l.*; 4 of 50*l.*; and Exhibitions of 30*l.*, all tenable for three years and renewable for a fourth.

II. No.

III. No.

IV. A small fund is available.

V. (*a*) No.

(*b*) Only when sudden financial disaster has overtaken the parents.

(*c*) Private liberality has never failed.

ST. PETER'S COLLEGE, CAMBRIDGE.

II. No; but grants in aid may be made from a fund for deserving students, but no grant would be made to an 80*l.* Scholar.

IV. Two private funds for deserving students administered by the Tutor with the cognisance of the Master; and a fund for the encouragement of research from which grants are made to students after graduation. No funds for complete maintenance of a student of exceptional promise.

V. (*a*) Cases may have occurred.

(*b*) I cannot remember any case.

SELWYN COLLEGE, CAMBRIDGE.

II. The endowed Scholarships may be supplemented from the Exhibition Fund if the scholar is regarded as reaching a higher standard, but two benefactions cannot be held together.

III. No limit.

IV. No.

V. (*a*) 'Yes, from time to time. Now and then it has been possible to interest private individuals to come to the rescue before or after the candidate comes into residence; but the College has no means at its disposal for the purpose.'

VI. 'I should suggest that local authorities should be prepared to subsist *all* candidates from their area which have reached the requisite standard in an open competition, instead of making their support dependent on a further competition for a limited number of local Exhibitions.'

NEWNHAM COLLEGE, CAMBRIDGE.

I. 5 Scholarships of 50*l.* for three years and 2 of 35*l.*, tenable for three years; 1 of 50*l.*, tenable for two or three years, and another of 50*l.*, tenable here or at Girton College for three years; 1 of 100*l.* for first year's students, tenable for three years; 1 of 40*l.* for one year for third-year students. A number of small grants, generally of 15*l.*, tenable with or without Scholarships; 5 grants of 5*l.* for books to students. All but one of above Scholarships are awarded annually.

II. Only as stated above.

III. No limit.

IV. A Loan Fund, from which as much as 30*l.* a year may be borrowed for three years. No other permanent endowment, though help may be given as stated above by means of the grants and Loan Fund and from private sources.

V. (*a*) No such cases.

(*b*) I believe not.

(*c*) Such resignations would be met by help from the grants and Loan Fund. By means of these a student holding the smallest of our Scholarships, one of 35*l.*, could make it up to 80*l.* (our fees are 90*l.*) with 15*l.* grant and 36*l.* loan. As a rule, however, we find that the students most in need of help have school Scholarships, and that their families are able to give them a little help.

UNIVERSITY COLLEGE, LONDON.

I. 44 Scholarships, varying from 10*l.* to 150*l.*; tenure varying from one to three years—'in two cases this may be raised to five.' Two Exhibitions of 57*l.* 15*s.*, tenable for three years; 2 Bursaries of about 16*l.*, tenable for two years.

II. Permission must be obtained to hold two College Scholarships at the same time, and in the case of the A. entrance Scholarships, the following Regulation obtains:

No student is permitted to hold an A. Scholarship concurrently with any other College Scholarship when the joint annual value of such Scholarships exceeds 50*l.*, except upon the special recommendation of the Professorial Board.

III. No.

IV. I have small sums placed at my disposal by friends of the College and members of the College Committee from time to time to help poor students, who are now greatly helped by County Scholarships.

V. (*a*) I have only known of one since my tenure of office here for the last nine years.

(*b*) In two cases during my tenure of office.

VI. I think it would be a good plan if all Scholarships, Exhibitions, and Bursaries were given practically as loans with the understanding that if and when a student, who had benefited from holding a Scholarship, found himself financially able to do so, he should return at least the sum that he had received. It has been done in one or two cases, but it should become a general policy and tradition.

KING'S COLLEGE, LONDON.

I. Scholarships (1 entrance), 1 of 30*l.* for one year (in alternate years); 2 of 25*l.* for two years; 2 of 30*l.* for three years; 2 of 25*l.* for four years; 2 (to Students of the College), 1 of 20*l.* for two years; 2 of 20*l.* for one year (first and second year's medical respectively); 1 of 20*l.* for five years (training of medical missionaries). Exhibitions, 2 of 25*l.* for two years (1 entrance).

Theological, 6 Exhibitions of 50*l.*, 5 Exhibitions of 20*l.*, and a few Bursaries at the discretion of the Dean.

II. Most of the above are entrance Scholarships, and not more than one can be held. The Regulations for the other benefactions make it impossible for more than one to be held at a time.

III. No limit.

IV. No regular fund, but Scholarships are sometimes supplemented by private benefactors.

V. (*a*) Yes, but not often.

(*b*) Yes, but not often.

(*c*) On rare occasions from general College funds.

KING'S COLLEGE FOR WOMEN, LONDON.

I. 2 Scholarships of 40*l.* for three years, each awarded once in three years; 1 of 30*l.* for one year (to second year Arts Students not necessarily of the College) in entrance Scholarships in Classics of 25*l.* for two years. Exhibitions of the value of 60*l.* for

three years are open. Five Bursaries in Theology, covering fees for one session, are given to members of the Church reading for Certificate or Diploma, and who show that they are in need of financial help.

II. Two Scholarships may and at present are held by a single beneficiary.

III. No.

IV. None.

V. (a) No.

(b) No. Had such a case arisen, I think that the College would undoubtedly have assisted.

GOLDSMITHS' COLLEGE.

I. None, except when the London County Council award a free place. They are entitled to award 15 in consideration of their annual grant towards the maintenance of the College.

II. ——.

III. Not by the College Authorities.

IV. None.

V. (a) Application for free places is made to the County Council. I am not, therefore, in a position to answer.

(b) Not that I know of.

ROYAL HOLLOWAY COLLEGE.

I. Scholarships, 4 of 60*l*., 7 or 8 of 50*l*. at entrance, tenable for three years. Bursaries not more than 6 of 30*l*., tenable for three years. After not less than three terms' residence, 3 at least of 30*l*. for three years, and 1 of 60*l*. for three years.

II. If two (entrance and other) are held together, a reduction of 15*l*. is made.

III. No limit.

IV. None.

V. (a) No successful candidate has declined a Scholarship, but there have been several cases where a successful candidate would not have been able to take up a Scholarship without the help she received, either from her school, or from a County Council or other awarding body. In the case of the smaller Scholarships, namely, Bursaries, it has happened in several cases that these benefactions have been declined as a candidate was unable to furnish the remaining amount required for the fees.

(b) and (c) So far as I know, no deserving beneficiary has been allowed to retire from her course through lack of means; but there have been cases where this retirement would have been necessary if the students had not received help from a Loan Fund which has been established in connection with the College.

VI. I think that there is great room for increase in the help given by local education authorities to promising girls in order to enable them to go to College. Where an examination for Scholarships is strictly competitive, as in the case of our own entrance Scholarship Examinations, and, I believe, the entrance Examinations of all other Colleges, and where the funds are strictly limited, only a small number can be helped by the College to take up their career. I feel sure that the British Association Educational Section could do much to educate public opinion in this very important matter.

BEDFORD COLLEGE FOR WOMEN.

I. Entrance Scholarships, 1 of 60*l*.; 4 of 30*l*.; 4 of 50*l*. tenable for three years; 1 Scholarship, 60*l*. for two years; 1 Fellowship (? post-graduate), 50*l*. for two years. Residence Bursaries, which reduce the fees of residence by 14 guineas, are given to students who are unable to pay the full fees.

II. No two College Scholarships may be held together, but a College Entrance Scholarship may be held with a Scholarship or Exhibition from another source by special permission of the Council. Residence Bursaries are sometimes awarded to Scholars.

III. The question has not arisen.

IV. (a) No. There is a small 'College Fund' supported by voluntary contributions, from which grants are made to needy students, but these grants are not as a rule made to scholars.

(b) Scholarships are occasionally supplemented privately, but in no case does this provide for a complete maintenance of the student.

V. (a) and (b) Not during the last six years.

WESTFIELD COLLEGE.

I. 5 to 7 Scholarships annually of 35*l.* to 50*l.* for three years (last year 7 were awarded, each of 50*l.*); 1 permanent endowed Scholarship of 50*l.* for three years, offered every third year.

II. No.

III. No.

IV. Private help is in many cases given to supplement Scholarships, and also to help students who do not hold Scholarships. I have arranged for this privately.

V. (*a*) I believe that in some cases a Scholarship or Bursary has been declined where the winner has failed to gain another Scholarship elsewhere to supplement the one offered by the College.

(*b*) I think not. Help has been arranged in case of need.

(*c*) I have arranged privately for help by gifts or loans, and have received some gifts for this purpose from members of Council, old students, and friends of the College.

VI. Examinations are not as a rule a *full* test of merit, and the help and most value are given to desirable students who have passed a *standard*, and when the personality and circumstances are taken into consideration.

UNIVERSITY OF DURHAM.

I. At entrance, 5 open Scholarships (to men and women) of 70*l.*; 1 of 40*l.*; 3 of 30*l.*, for one year, renewable for a second and third year; 1 of 70*l.*, for women only; an Exhibition of 30*l.* for students of limited means; 3 second year's Scholarships of 30*l.*, one restricted to those who do not hold any Scholarship or Exhibition, and two Exhibitions of 40*l.* restricted to candidates for the B.A. in Theology. A number of close Scholarships and Exhibitions, ranging from 50*l.* to 8*l.*, all for one year (except two for three years).

II. No holder of a Foundation Scholarship can hold together with it any other Scholarships or Exhibitions (except two University and two close Scholarships for Graduates) which will with it amount to as much as 100*l.* a year.

ARMSTRONG COLLEGE, NEWCASTLE.

I. (*a*) At entrance, Exhibitions, 2 of 15*l.*; 1 of 20*l.* for one year, tenable and renewable for a second year, subject to satisfactory conduct and progress; 20 Exhibitions of free admission to the courses for two years, renewable for a third under same conditions; with these may be provided Bursaries for successful candidates who, without such aid, would not be able to accept the Exhibitions; 2 close Exhibitions, giving free admission to Degree course (same conditions). County Council Scholarships and Exhibitions (restricted locally), 2 of 60*l.*; 2 of 50*l.*; 2 of 40*l.*, plus tuition fees, tenable for two years only; 1 yearly of 50*l.* in Marine Engineering, for three years, restricted to candidates who can produce satisfactory evidence that the amount will enable him to pursue his day courses, and that he would be unable to do so without this aid; 3 Scholarships in Naval Architecture of 50*l.* under same conditions.

(*b*) At close of first year, a Scholarship of 30*l.* or under for one year, plus remission of two-thirds of the class fees; 1 of 20*l.*, with similar remission for three years; 1 Scholarship of 15*l.* for one year; 1 of 13*l.* 10*s.* for one year (renewable under conditions for a second).

(*c*) At close of second year, 2 Scholarships of 40*l.* (with remission of laboratory fees), and other money rewards and prizes.

II. The second year's Scholarships and Exhibitions are not tenable with any other.

THE VICTORIA UNIVERSITY, MANCHESTER.

About 24 Foundation Scholarships, awarded by the University. A large number of entrance Scholarships, awarded by other bodies, varying from 25*l.* upwards; 12 Exhibitions of 15*l.* upwards; numerous prizes of books and money.

II. 'No . . . Scholarship or Exhibition awarded by the University shall be held together with any other . . . Scholarship awarded by the University or with any County Council School, without the express permission of the Senate. In the case of students who hold other . . . Scholarships or Exhibitions of any kind the Senate shall have power to withhold, either in whole or in part, payment of any . . . Scholarship or Exhibition awarded by the University. In the case of . . . Scholarships, Exhibitions, and Bursaries awarded by a Hall of Residence no such permission is necessary (University Scholarships are frequently held with County Council Scholarships up to a maximum of 75*l.* by special permission of the Senate).'

III. The Regulation stated above limits concurrent tenure, but there is no fixed maximum limit as to the amount a single beneficiary may hold laid down by the Regulations.

IV. Not at present. A small sum is set aside for assistance to deserving students to enable them to complete their course in case of special need arising.

V. (*a*) Yes, but not frequently.

(*b*) I cannot recollect such a case.

(*c*) Under very special circumstances a supplemental grant has been made from the Scholarship Suspense Account, or private loans have been given.

UNIVERSITY OF BIRMINGHAM.

I. (*a*) On entrance, 15 of remission of fees plus maintenance not exceeding 30*l.* for four years (city residents); 2 of 25*l.* for one year; 1 of 24*l.* for two or three years (Wolverhampton students); 1 of 50*l.* and 1 of 40*l.* for three years (Faculty of Commerce); 2 Bursaries of 45*l.* for three years (parents' income not exceeding 150*l.*); and one of 13*l.* (residents of Smethwick) for one year, renewable.

(*b*) Second and later years in Science, Arts, and Commerce, awarded mostly on Intermediate Examination, 1 Scholarship of remission of fees for three years (pupils of Technical School); 1 of 40*l.* for three years; 1 of 25*l.* for two years, and 1 of 36*l.* for 1 year (limited to pupils from King Edward's Schools); 1 of 50*l.* and 1 of 40*l.* for three years (Commerce); 1 of 37*l.* for one year (Science and Metallurgy); 4 Exhibitions of 30*l.* for one year.

(*b*) Medicine, 1 of 21*l.* for 2 years; 1 of 14*l.* for one year (orphans of medical men); 4 of 10*l.* 10*s.* for one year on results of second, third, fourth, and final examinations.

II. No.

IV. We have no funds at our disposal of a permanent kind to supplement Scholarships for the complete maintenance of students of exceptional merit. We provide, however, out of ordinary revenue for maintenance up to 30*l.* per annum, in respect of 60 University Entrance Scholarships, tenable by candidates resident in the city.

(*a*) The amount to be expended in any year on Scholarships and Bursaries respectively in any year is in the discretion of the Committee, and is determined by the applications received. Bursaries may provide for complete maintenance; their amount depends on the circumstances of the applicant and of his parents or guardians.

(*b*) No.

V. I do not remember any instances of (*a*) or (*b*).

THE UNIVERSITY OF LEEDS.

I. Entrance Scholarships, 2 of 20*l.* and 1 of 21*l.* for two years; 3 of 40*l.* for two years for a third; 2 of 25*l.* and 1 of 35*l.* renewable; and a number of Scholarships on the award of public bodies. The Leeds City Entrance Scholarship Fund is now utilised 'for the purpose of extending the courses of deserving and necessitous Leeds students attending at the University.'

II., III. 'Power is reserved to declare a Scholarship vacant or reduce its value on the ground that the Scholar has previously or subsequently to his election acquired another Scholarship. In cases where students hold Scholarships the aggregate amount of which amounts to more than 75*l.*, the Senate reserves power to reduce them to this sum.'

IV. I am not quite clear as to the intention of this question. We have no fund which is necessarily used as a means of supplementing Scholarships, but some of the Scholarships and other awards may be given to students already holding some other Scholarship. Special grants have also been given by the University to Scholarship holders.

V. (*a*) (*b*) and (*c*) The information available is not sufficiently definite for a reply to be given to these questions. If such cases have occurred, they have been very rare. Special grants have been made to Scholarship holders by the University, and private help has sometimes been forthcoming.

UNIVERSITY OF BRISTOL.

I. Scholarships, 3 of 30*l.* to 34*l.* for one year; 1 of 25*l.*, for not exceeding three years; 1 of 20*l.* for one year; 'City Scholarships' (variable, dependent on applications and qualifications of students, remission of fees) for one year renewable; 'City Bursaries,' under same conditions, for maintenance, purchases of books or apparatus.

II. 'Not as a rule.'

III. No.

V. No.

University of Sheffield.

I. Scholarships and Exhibitions:

1 every year, tenable during whole degree Course, 122*l.* a year.
8 every year, tenable for three years, 50*l.* a year.
2 " " " 30*l.* a year.
11 " " " { 15*l.* first year, *plus fees remitted.* / 20*l.* second year " / 25*l.* third year "
2 " " " 50*l.* a year "
1 (triennial), tenable for three years, 50*l.* a year.
1 " " " 21*l.* a year.
4 (annual), tenable for one year, Fees of Degree Course remitted.
1 " " " Fees in Engineering or Metallurgy remitted.
1 " " " 20*l.*

Medicine.

1 " " one year 20*l.*
4 " " " 50*l.* plus fees remitted.

In addition, the Surveyors' Institute offer 1 Scholarship of 60*l.* and 1 of 50*l.* for three years, tenable in this University.

II. Only with the special permission of the Council and Senate of the University.

III. Not specifically; but the regulation cited in answer to II. provides a check against any student receiving too large a sum in Scholarships.

IV. No.

V. (*a*) Not to my knowledge. I think I should be justified in saying No.

(*b*) No.

University College, Nottingham.

I. Scholarships, 1 of 12*l.* for one year, renewable at the discretion of the Council College Studentships (16 during 1912–13) of 10*l.* to 18*l.* awarded on results of Terminal and Sessional Examinations to College students who are in need of pecuniary assistance, tenable for one year, renewable. City Education Bursaries of 10*l.*, with remission of College fees, averaging 18*l.*

II. Under exceptional circumstances the College Council might sanction a Studentship being held together with one of the above-named Scholarships. It is possible for holders of College Scholarships and Studentships to hold Scholarships awarded by another body during the same period.

III. No. In awarding Scholarships, however, the pecuniary circumstances are in some cases taken into consideration.

IV. No.

V. (*a*) Very few such cases have occurred.

(*b*) The College Studentships are designed to meet such cases.

University College, Reading.

I. Scholarships and Exhibitions releasing the holder from payment of College fees wholly, or in part; *or* contributing towards the cost of his or her maintenance while at the College. Major Scholarships, 2 of 69*l.*, 1 of 65*l.*, at entrance, tenable for two years, renewable for a third. Two minor Scholarships of about 20*l.* (*i.e.* remission of tuition fees) under same tenure. Exhibitions, several, of which only the Gallia (10*l.*), awarded to Matriculated Students in French, is available for ordinary undergraduate students.

II. Not two College benefactions in ordinary circumstances. Comparatively small Exhibitions, however, may be awarded to students holding other Scholarships or Exhibitions. The Committee governing our halls of residence also occasionally make small supplementary grants to students who already may be holding Scholarships or Exhibitions, if the cases seem to make such a course desirable.

III. We have no definite rule. . . . In this institution, during many years, I have only known one case in which it could fairly be said that perhaps the candidate was receiving too much money. In that case, he was not receiving Scholarships from the College at all, but derived them from other quarters.

IV. Our chief Hall of residence for men has an endowment, the object of which is—provided that the working expenses of the Hall have been first defrayed —to enable Scholarships and Bursaries to be granted to students in residence at the Hall. The full scheme is not yet in operation, but ultimately there should be, in a Hall of 77 students, about 6 scholars in receipt of about 40*l.* a year each,

and possibly more holders of Exhibitions and Bursaries of smaller sums. We shall also be in possession quite shortly of an endowment to provide a Scholarship of 60*l.* a year, tenable by a candidate from R. School. Apart from these instances, we have occasionally given Scholarships temporarily out of our College income, or they have been provided by special gifts. I am not aware that we have ever given a Scholarship which involves "complete maintenance." In our opinion, such a course would be rarely desirable.

V. I do not remember a case of (*a*) or (*b*). The College has frequently, on the other hand, assisted students who could not complete their College course without some special assistance in addition to that which they might already be receiving from other sources.

VI. It is not quite clear to me what the precise purport of these inquiries is. Consequently, I am afraid that the information I have given may not be of much use. The most important observation, based on experience, that I can offer on the subject of Scholarships would be this: that while entrance Scholarships serve a certain obvious purpose, far too much stress has been laid upon the importance of having a large supply of them, without giving sufficient importance to their duration. That is to say, it is of very little use for a local education authority or other body to give a Scholarship for two years unless it has quite clearly made up its mind that—except the candidate fails in conduct or progress—the Scholarship will be extended, not only for a third year, but for a fourth. Extraordinary difficulty is experienced in persuading local authorities to extend any Scholarship for a fourth year, and yet it is precisely that fourth year which, in the case of University students, is the most important of all. Over and over again at this College our students have been placed in a difficulty in the final year of their course. The difficulty arises in any kind of University course, but I will give an instance of which I have had two recent examples. Two women students, holding Scholarships from local authorities, successfully obtained their degree after probably in each case three years' work, not more, and possibly less. These students wish to become teachers in secondary schools. Consequently, they wish to remain at the College for another year in order to go through a course of secondary training and get a certificate. Unless they do this, they will stand very little chance of getting posts for which trained candidates are in competition, and yet in both cases—the cases of the two Education Committees—opposition is shown to the extension of the Scholarships for these purposes. In one case, the Education Secretary writes to say that the course of secondary training appears to him to be similar to a course of preparation for a civil service examination, and, in his opinion, not a course for which a Scholarship should be continued. The same Secretary, I believe, puts into his advertisements for vacancies in the staffs of his county secondary schools that only trained candidates need apply. At this College we have recognised that the most imperative need of all is for Scholarships that would take effect during the third and fourth and even fifth years of a student's stay with us. We consider that these are more important than entrance Scholarships, and that nothing would benefit a University institution more than for it to be known that, notwithstanding a comparatively small supply of entrance Scholarships, there is a probability that any hardworking and promising student will be enabled to complete a long course of study, including probably a period of post-graduate study. We have already decided that such funds as we possess available for such purposes will be used in accordance with these principles when the College becomes a University in two or three years' time.

University College, Aberystwith.

I. 37 Scholarships and Exhibitions, 1 of 54*l.*; 3 of 40*l.*; 1 of 35*l.*; 1 of 27*l.*; 4 of 30*l.*; 1 of 20*l.*; 2 of 15*l.*; 14 of 10*l.*; 1 of 6*l.* Of these, 1 is tenable for four years, 18 for three years, 12 for two years, 6 for one year.

II. No two of these are tenable together, but students may hold them together with Scholarships from other sources outside the College.

III. No limit is imposed on the annual income derived from emoluments of all kinds by a single beneficiary.

IV. There is no benefaction for the complete maintenance of students of exceptional promise.

V. (*a*) Cases have occurred. 'Occasionally the College can be of assistance by obtaining private aid, but as a rule this is not possible.'

(*b*) 'Cases have also occurred of deserving beneficiaries retiring during their course

through lack of adequate means; but in most cases they have taken posts in schools or otherwise, and have subsequently returned to College to complete their course.'

(c) 'The Principal and Registrar have at their disposal a small loan fund from which they make periodical grants to deserving students, free of interest.'

UNIVERSITY COLLEGE, BANGOR.

I. Entrance Scholarships, 1 of 40*l.*; 1 of 30*l.*; Exhibitions, 1 of 20*l.*; 4 of 10*l.*, tenable in the first instance for three years, but may be extended for a fourth; and a number of limited Scholarships and Exhibitions, the highest of 30*l.*, the longest tenure three years.

II. 'No two College benefactions can be held together.'

III. No limit has hitherto been imposed.

IV. We have no permanent endowment or benefaction for this purpose. There is, however, a 'Loan Fund' from which advances (repayable without interest) are made to students who are unable without such assistance to complete their courses.

V. (*a*) We do not know of any case . . . great sacrifices are often made by the parents of students in order to enable their children to come to College, and in many cases friends in the locality from which a student comes render assistance.

For the Bursaries, etc., at the Scottish Universities, see Parliamentary Paper 411, 11 Dec. 1912.

ST. ANDREWS.

I. The value of the Bursaries on entrance and their tenure, as given in the Parliamentary Paper, are from 6*l.* 10*s.* to 50*l.* respectively, and their tenure varies from three to eight years. In addition to these, 7 Bursaries of 16*l.* 5*s.* to 30*l.*, tenable for two or three years, and two in the fourth year of 20*l.* and 45*l.* respectively, have been awarded.

An additional entrance Scholarship of 30*l.* for four years has been founded for women students. As a rule, the Bursaries on entrance run only for three years, in a few cases for four; and 6 Scholarships of 80*l.* for 1 year, 4 of 50*l.* for two years, and 5 of 50*l.* for one year, and one of 80*l.*, tenable at Oxford or Cambridge, are not included in the White Paper (some are post-graduate).

II. Not as a general rule; but in the case of second-year Bursaries, they may be awarded to a student, notwithstanding he already holds a Bursary gained at entrance.

III. No general rule imposing a limit. The rule just quoted to some extent secures that there will be no undue accumulation of Bursaries in one person. As regards outside Bursaries over which the University has no control, the case is provided for by a rule that no one shall be entitled to hold a Bursary in the University with any outside Bursary yielding an annual income greater than 30*l.*, and tenable during a period of three years. The University authorities may at any time alter this regulation.

IV. There is a small fund raised some years ago to enable Foundation Bursaries to be supplemented. Two other funds left to the University without any reservation may be devoted to the augmentation of existing Bursaries.

I do not remember any case, however, where money from any of these sources has been drawn upon for the complete maintenance of any student. Of course, in Scotland, the existence of the Carnegie Fund Trust for the Universities of Scotland, which up till recently practically paid the class fees due by a student qualified to obtain that benefit, forms a considerable supplement to the Bursary Fund. Students may have their fees paid and hold a Bursary of from 15*l.* to 40*l.* a year, in which case the latter source of income provides for their maintenance.

V. (*a*) I do not recollect such a case within my experience. Of course, the cases are numerous in which candidates who were relying on assistance from the Bursary Funds have been obliged, owing to their failure to obtain a Bursary or to some other financial casualty, to defer entering the University, or to leave the University midway in their career. No statistics and no definite note has been kept of such cases. I do not think that in the case of a student of exceptional ability it could easily occur.

(*c*) The University is enabled, out of a fund made up of the income from Bursaries which from various causes have lapsed, to provide for the encouragement of students of small means where they are known to have merit; and that more particularly where, having struggled on through the curriculum for an ordinary degree, the student

desires to obtain honours. The University Court have provided, to meet that case, for grants being made to students of the fourth and fifth year of study. As a rule, the ordinary Bursary or University Scholarship at entrance runs only for three years, in a few cases for four.

UNIVERSITY COLLEGE, DUNDEE.

I. Bursaries, entrance, 12 of 15*l.*; second year, 4 of 20*l.*, 2 of 15*l.* Third, fourth, and fifth years each one of 20*l.*, all tenable for one year only. Other Scholarships and Bursaries in the gift of other bodies or patrons tenable, held mostly at this College, are one of 60*l.* for two years; 2 of 25*l.* for three years; 1 of 25*l.* to 30*l.* for three years; 5 of 40*l.* for three years.

II. As a rule not; but exceptions are allowed in special deserving cases.

III. This question is answered in the negative in reference to Answer II.

IV. No.

V. (*a*) and (*b*) No.

VI. A Committee of the College Education Board is at the present moment investigating the whole question of the awarding and tenure of Bursaries concerning the College, whose Report is expected before the close of the current academical year.

UNIVERSITY OF GLASGOW.

I. Reference only to Parliamentary Paper. For undergraduates are provided a large number of Bursaries of which few are over 40*l.* a year, 60*l.* being the highest; tenable mostly for three or four years (the longest tenure is seven years). Exhibitions and Scholarships are all post-graduate.

UNIVERSITY OF ABERDEEN.

I. Reference to Parliamentary Paper. Maximum value, 38*l.*; tenure one, two, or three years, mostly four years, some five years, some seven years. A fund of 322*l.* awarded in Bursaries of varying amount to such students as may require pecuniary assistance to prosecute their studies at the University.

II. No; but a student may hold a Bursary of the University along with such a Scholarship as the Ferguson, which is open to all Scottish Universities.

III. No.

IV. No.

V. (*a*) and (*b*) Not that I am aware of.

UNIVERSITY OF EDINBURGH.

(Compiled from Calendar and Parliamentary Paper.)

I. 10 Scholarships of 100*l.* for three years, open, after completing second year; 1 of 27*l.* for two years (after 1 course in Natural Philosophy); Bursaries, 235, ranging from 10*l.* to 50*l.*; 1 of 53*l.* 15*s.* 4*d.*; 1 of 91*l.* 12*s.* 8*d.*; tenure, mostly one to four years, some of five, ten of six, and one of seven years.

TRINITY COLLEGE, DUBLIN, AND UNIVERSITY OF DUBLIN.

I. 70 Foundation Scholarships given at various stages, and tenable till degree standing of 18*l.* 9*s.* 4*d.* yearly. 14 Non-foundation Scholarships of 30*l.* under same tenure, for women students. Twenty Roll-keepers, markers, &c., from 7*l.* to 20*l.* yearly, and Provost's marker with 45*l.* yearly; 30 Sizarships, 5 Reid Sizarships, 5 Sizarship Exhibitions, emoluments not specified; 4 lady Sizarships of 12*l.* Exhibitions from 4*l.* 12*s.* 4*d.* to 20*l.*, 25*l.*, and in two cases 50*l.*

II. Yes.

III. No limit.

IV. None for complete maintenance.

V. (*a*) and (*b*) No.

THE QUEEN'S UNIVERSITY, BELFAST.

I. (*a*) Foundation Scholarships, junior, 40 of 40*l.*, tenable for one year; 3 of 40*l.*, 6 of 30*l.*, 4 of 20*l.*, 3 of 15*l.* in the Faculty of Medicine; 3 of 20*l.* in the Faculty of Law, and 6 of 20*l.* in the Faculty of Commerce. Extra Scholarships may, in special circumstances, be offered for competition among Art(s?) Students entering upon their second or third year.

(*b*) Private endowment, 1 of 20*l.*, on entrance, for one year, renewable for a second and a third year; 3 Sullivan Scholarships of about 40*l.*, for three years, on entrance, restricted to national teachers or assistant teachers; 2 of 20*l.* for one year; 1 (Megaw) of about 40*l.* for one year (restricted to Christians); 1 of about 40*l.*, payable in three

annual instalments; 1 of 10*l.* and 1 of 5*l.* in Commerce, tenable for two years; 1 of about 27*l.* for women, payable in three annual instalments; 1 Exhibition of 27*l.* for Undergraduates in Arts; 2 entrance Exhibitions (Drennan and Tennent) of 5*l.* each at entrance.

(*c*) In addition to these the City and County Borough of Belfast offers annually 4 Scholarships of 40*l.* annually for three years (which may be extended to a fourth or fifth, in the case of exceptional merit or excellence), tenable by matriculated students of the University. Candidates must show that they are in need of assistance.

(*d*) The following County Scholarships and Bursaries are also tenable at any University in Ireland, all for three years, in the University of Belfast, Antrim, 2 of 40*l.*; Donegal, 2 of 45*l.*; Kildare, 4 of 50*l.* (Catholics excluded); Monaghan, 3 Scholarships of 50*l.* and 3 Bursaries of 25*l.* (Catholics excluded); Westmeath (only tenable in the University of Belfast and the National University), 3 of 50*l.*; Wexford, 3 of 50*l.*, and 3 Bursaries of 25*l.* (Catholics excluded).

II. 'Except where otherwise specified, no Scholarship can be held in conjunction with Scholarships or Exhibitions.' A Sullivan or Megaw Scholarship, or a Drennan or Tennent Exhibition may be held with a Foundation Entrance Scholarship.

V. (*a*) and (*b*) Not to our knowledge.

University College, Cork.

I. Entrance Scholarships, College 12 (3 of 40*l.*, 6 of 30*l.*, 3 of 20*l.*) for one year; 3 Honan (for those whose financial position is such that it would be impossible to obtain a course of instruction for a University degree without this aid); 3 of 50*l.*, renewable up to a fifth year.

Later years, Faculties other than Medicine and Engineering, 2 of 40*l.*; 2 of 30*l.*; 4 of 20*l.* for second year, renewable for third year. Engineering, 1 of 30*l.* for second year; 1 of 30*l.* for third year. Medicine, 3 of 30*l.* for second year; 3 of 30*l.* for third year, 3 of 30*l.* for fourth year, renewable for fifth. Law, 1 of 10*l.*, awarded at end of first year. Exhibitions may be awarded in every case to students of merit who have failed to obtain Scholarships.

County Council Scholarships, tenable in the College:—

Cork: 10 of 24*l.*, tenable for three years and renewable for a fourth or fifth; increasable from the Reserve Fund up to 50*l.* in such cases as may seem advisable; 100*l.* per annum, rising in the third year, to be allocated to Bursaries of lesser value to promising students, not worthy of Scholarships.

Kerry: 2 of 50*l.*; 3 of 30*l.* (restricted in respect of calling and means of parents) for one year, renewable for a second to a third year.

Waterford: 3 of 50*l.* and 1 of 30*l.* for three years (may be extended to fourth and fifth year).

Other Scholarships are offered by the County Councils of *Limerick* and of *Tipperary* (North and South Ridings).

II. No. But there are practically no outside ones that could be tenable with ours, except possibly from Trinity College, Dublin.

IV. (*a*) Only in the case of the County Cork scholars, who may be helped from the 'Reserve Fund' 'where necessary' in the judgment of the President of the College.

(*b*) No regular stream.

V. (*a*) and (*b*) Yes.

(*c*) In some cases by private beneficence.

VI. It is desirable that there should be at the disposal of the College a fund earmarked to supplement Scholarships, &c., for the complete maintenance of students of exceptional merit.

APPENDIX II.

LIST OF TOTAL EMOLUMENTS HELD ON ENTRANCE BY STUDENTS IN THE UNIVERSITIES OF OXFORD AND CAMBRIDGE.

(Arranged in Order of Values.)[1]

A. *Oxford.*

No Emoluments Accepted	1
£20	2
21	1
30	7
33	1
40	10
50	10
60	10
70	2
75	1
80	45
82 10*s.*	1
89	4
90	11
100	19
105	4
106	3
110	7
115	1
117 14*s.*	1
120	15
121	1
125	4
126 1*s.* 6*d.*	1
130	17
133 16*s.* 8*d.*	1
135	3
136	1
140	10
143	1
145	1
150	12
151	1
152	1
155	2
160	5
170	6
180	5
185	1
230	2
Total	231

B. *Cambridge.*

£20	2
25	3
30	19
32	1
33	1
35	5
40	21
50	7
57	1
60	14
65	2
67	1
70	5
74	1
75	3
80	15
85	3
90	11
91	2
93	1
95	1
100	16
105	2
110	9
111	1
112	1
115	6
120	6
125	3
130	8
135	6
138	1
140	7
145	3
150	13
154	1
155	2
160	5
164	1
170	1
175	1
178	1
180	3
188	1
190	3
300	1
Total	221

[1] Compiled from the detailed tables supplied on behalf of the Universities' 'Minutes of Evidence' to the Royal Commission on the Civil Service, Jan. 9–24.

Corresponding Societies Committee.—Report of the Committee, consisting of Mr. W. WHITAKER (*Chairman*), Mr. W. P. D. STEBBING (*Secretary*), Rev. J. O. BEVAN, Sir EDWARD BRABROOK, Dr. J. G. GARSON, Principal E. H. GRIFFITHS, Dr. A. C. HADDON, Mr. T. V. HOLMES, Mr. J. HOPKINSON, Mr. A. L. LEWIS, Rev. T. R. R. STEBBING, Mr. WILFRID MARK WEBB, *and the* PRESIDENT *and* GENERAL OFFICERS. (*Drawn up by the Secretary.*)

THE Committee recommend that the Hampstead Scientific Society be raised from the status of an Associated to that of an Affiliated Society. An application for affiliation has been received from the Child Study Society, but its constitution and the rules of the Association governing Affiliated Societies have prevented its election.

The Midland Institute of Mining, Civil, and Mechanical Engineers being affiliated to the Institute of Mining Engineers (an Affiliated Society) has resigned its affiliation. The Warrington Field Club has resigned its position as an Associated Society, as its membership, already below fifty, is still decreasing. The Dover Sciences Society, the Hull Society of Natural Science, the Penzance Natural History Society, and the Scottish Microscopical Society, as they have not renewed their applications for association, have been removed from the list.

Dr. P. Chalmers Mitchell has promised to preside at the Conference of Delegates at Birmingham and to deliver an Address with the title 'Utility and Selection.'

The Committee recommend the following subjects, suggested by the Yorkshire Philosophical Society and the Belfast Naturalists' Field Club, for discussion at the Conference: 'The Relationship of Local Museums with Educational Institutions,' to be introduced by the Rev. William Johnson, and 'The Best Means for Preventing the Extinction of Local Species,' to be introduced by Mr. R. H. Whitehouse. Mr. A. R. Horwood, of Leicester, will also open a discussion on 'Scientific Societies and the Control of Plant Extermination.'

Consideration will be given at the Conference to the desirability of holding next year's Conference at Havre during the meeting of the French Association for the Advancement of Science.

The Committee announce that through the good offices of Dr. Jessie White and Professor F. W. Gamble a room will be set aside for the use of the delegates during the Association's visit to Birmingham.

The Committee desire to draw attention to the valuable collection of Local Scientific Societies' Proceedings housed at the British Association's offices and available for reference.

The Committee ask to be reappointed and apply for a grant of 25*l.*

Report of the Conference of Delegates of Corresponding Societies held at Birmingham, September 11 *and* 16, 1913.

Chairman . . .	Dr. P. Chalmers Mitchell, F.R.S.
Vice-Chairman . .	Sir George Fordham.
Secretary . . .	W. P. D. Stebbing, F.G.S.

First Meeting, *Thursday, September* 11.

Dr. P. Chalmers Mitchell presided, the Corresponding Societies Committee being represented by the Rev. J. O. Bevan, Sir Edward Brabrook, Principal Griffiths, Mr. J. Hopkinson, and Mr. W. P. D. Stebbing.

The business was opened by the reading of the Report of the Corresponding Societies Committee. The Chairman then delivered his Address, entitled :—

Utility and Selection.

The greatest paradox of philosophy is that each of us is the only begetter of the universe in which we live, that the world is an extension of the individual mind. The hardness and roundness of a pebble exist because we think they exist; the stars of the high heavens twinkle in us; pain and pleasure, revolving time and illimitable space are qualities or categories of our mind. I have called it the greatest paradox, for a paradox is great in the proportion that it is true. The universe is a creation of the human mind, an artifact of the instrument that apprehends it. I am not here to discuss philosophical realism and idealism, or to expound the converse of the paradox. Those who lose themselves in the airy mists of philosophy are not to be pitied; they may contentedly play by themselves the game of Hamlet with Polonius, doubling the parts.

Hamlet : Do you see yonder cloud that's almost in shape of a message from the dead?
Polonius : By the mass, and 'tis like a message from the dead.
Hamlet : Methinks it is a spirit.
Polonius : It is disembodied like a spirit.
Hamlet : Or like a spook.
Polonius : Very like a spook. *Hamlet, Prince of Denmark*, iii. 2.[1]

But I would remind you that if there be an objective reality, as we all must believe, of which our universe is a pale reflection, that reflection owes its character and its quality as much to the powers and imperfections of the reflecting instrument as to the objective reality. Our attempt to comprehend nature can be no more than an attempt to recreate it within the categories of the human mind.

Man has been defined as a rational animal, and there is no more persistent quality of his mind than the craving for teleological interpretation. He is uncomfortable in the presence of any phenomenon, until he is satisfied that it fulfils a purpose which he conceives to be useful. This point of view dominated the theologians and the rationalists of the eighteenth century, and in the nineteenth it led Darwin to one of the greatest triumphs of the human mind, and filled the armoury of the opponents of Darwinism.

If we can assign utility to a character in an individual, we agree readily that its possession by most individuals may be an advantage to the species in the struggle for existence. We agree also that as characters vary in individuals (whether the variations be large or small, continuous or discontinuous, does not affect the argument), the average of these in the members of the species may be intensified in the course of generations, if they fit the environment, or smeared and obliterated if they are out of gear with the environment. Having gone so far, we have accepted the main principle of Darwin's theory of evolution, a principle so harmonious with our mental disposition that it has become almost

[1] Unauthorised edition.

personified and has displaced the other gods in high Olympus. Many of the adherents of the new god have assigned to it an immanence of which Darwin did not dream. They believe it to be universal and all-powerful, and that the partisans of any other principle are like the ignorant heathen, bowing down to wood and stone. One of the disadvantages of this pathological distortion of Darwinism is not only that it has misled the elect, but has given a welcome opportunity to the crafty depreciators of the achievements of science, and to the clamorous advertisers of new theories. In attacking the excrescences of Darwinism, they persuade themselves and try to persuade others that they are establishing the bankruptcy of science, or clearing the way for their own nostrum.

I believe it to be historical truth that Darwin convinced the world of the fact of evolution by his exposition of the principle of natural selection, that no principle has been suggested before or since more in harmony with the observed facts of nature, or more congruous with the processes of human intelligence. Using for a moment the erroneous language of personification, which is so convenient to employ and so difficult to avoid, I believe that natural selection has been the active agent in bringing about evolution, and that in a sense it may be said to have produced the material on which it acts by the processes of summation and obliteration. But Darwin never even suggested that all characters came into existence because they were useful, that the marks by which systematists find it convenient to distinguish species must be useful, or that the initial stages of a new character must be useful. Living beings are limited or determined by their inherited structure, by the inevitable necessities of their mode of growth and mode of living. Their parts and functions are linked by a thousand correlations, structural and functional, so that a change in any organ reverberates through the system. Living beings abound in characters and qualities of which no utilitarian explanation is possible. Such characters may be associated with other characters that are useful; they may have been useful in the past, in a different environment; they may never have had 'selection-value,' but a change in the environment or an alteration in the kaleidoscopic interrelations of the whole organism may give them 'selection-value.' They are material ready for natural selection, and so far from being vague and inchoate, may have a high degree of definiteness and complexity.

I propose to invite your attention to some examples of characters and qualities that, so far as we can see, are not present because they are useful.

The process of oxidation always accompanies living activity, and some of the chemical energy is liberated in the form of heat. Probably in plants and in the animals that we speak of as 'cold-blooded' the discharged heat is practically a waste product. The temperature of the tissues must be above freezing-point for the vital processes to be active, and each kind of organism has a euthermal range, a few degrees of temperature within which its organic processes succeed best. The heat produced by internal oxidation, however, does not appear to contribute in any important respect to the production or maintenance of the requisite temperature. Most organisms are ruled by the surrounding media, their activities rising and falling with the external temperature. If they have the power of movement or locomotion, they may turn or crawl to the sun, or seek the shade, but changes of weather and the recurring seasons are the dominating factors in their lives. Even the higher reptiles depend directly on the circumambient media. A few years ago, we improved the heating-system in the London Zoological Gardens, with the result that there was an increase in the frequency with which the reptiles fed, and a rise in their activities. If you wish a little torpid water-tortoise or a young alligator to take food, you must place it in a warm bath, precisely as many chemical reactions will not take place until you heat the mixture over a spirit-lamp.

Birds and mammals, the 'warm-blooded' creatures, have a fixed and rather high euthermal state, and depend chiefly on their internal production of heat to produce it. The normal temperature of the human body is 98·4° Fahr., and this may be taken as a fairly typical mammalian temperature, the normal for birds being a little higher. There is no more certain indication of illness, of the existence of something wrong in the bodily functions, than an important rise or fall in the temperature, and we feel ill even when the variation is small. Certainly we take notice of changes in the surrounding media, and after a time may be affected by them, so that we try to avoid extreme heat and extreme cold.

But when we are in good health, the height of the barometer, the intensity of light, and the dampness or dryness, purity or impurity, of the air, affect us even more than the actual temperature. We rely on the physiological mechanism by which the production and waste of heat respond to surrounding changes and cause the actual temperature of our tissues to remain almost constant. Very young mammals or birds, and all warm-blooded creatures when they are ill, have a feebler control of their own temperature, and the heat metabolism of the body has to be assisted by a more rigorous choice of environment, if the normal temperature is to be maintained.

There is thus a marked contrast between warm-blooded and cold-blooded organisms, which I may impress on you by asking you to compare an insectivorous bird and an insectivorous lizard. Both are swift and restless creatures which have to expend much energy in capturing their watchful and rapid prey. The alimentary canal and, so far as we know, the physiological processes of digestion are much alike in the two. The euthermal temperature is nearly identical, although the bird is more strictly limited to about 100° Fahr. and the lizard has a wider range. But the bird uses the heat of the oxidation processes in its own tissues to produce the temperature it requires, and so maintains its activity in spite of surrounding changes. If it be provided with suitable food, it can endure the cold of winter and heat of summer, and can adapt itself to a great range of climate and locality. The lizard cannot abide by its own production of heat; it is limited by the surrounding conditions, and becomes torpid or dies when the external cold is too severe or the external heat too great.

The evidence shows that warm-blooded mammals and birds are the descendants of cold-blooded reptiles. In the course of that evolution, the power of retaining and controlling the heat produced by oxidation in the tissues must have been acquired. No one can doubt the high utility of this power or its great advantage in the struggle for existence, as it widens the possible geographical range and increases the viability of its possessors. No one can doubt but that this kind of character would have come under the operation of natural selection. I desire to impress on your attention that the production of heat existed before it became useful. It was a waste product, an accident of the metabolism of the body, material ready for natural selection.

An important part of the provision for heat-regulation in warm-blooded animals is the coat of fur or feathers that serves to ward off the inclemency of the weather, and to prevent waste of internal heat by radiation and conduction. When small birds are roosting in the open air at night, their sleek plumage becomes ruffled, each feather standing out at right angles to the surface of the skin, changing the smooth contours of the body into a globe of fluff. Exposure to cold similarly induces erection of the fur of most mammals, and the effect of cold on our own naked skins, that we call 'goose-flesh,' is doubtless a surviving action of the mechanism that erected the hairs of our ancestors. Such devices control the loss of heat to a notable extent, but they are far from complete. If we had organs as sensitive to radiant heat as our eyes are sensitive to radiant light, the bodies of warm-blooded birds and mammals would be perceptible to us in the dark, in inverse proportion to the efficiency of their heat-retaining covering. They would be perceptible in no vague fashion, but in what I may call some kind of contour, due to the different intensities of heat-discharge from differently protected parts of the body. There would be creatures radiating an even glow, flashing intermittently, banded, spotted, and irregularly surfaced.

If enemies of warm-blooded animals were armed with such a power of appreciating differences in temperature, the mechanisms for preventing loss of heat by radiation would acquire a new selection-value. Such enemies cannot be said to exist, but there is a suggestion of the possibility in the behaviour of ectoparasites. These seem to have some kind of directive heat-sense. Everyone who has had to handle the fresh bodies of dead warm-blooded animals must have noticed how quickly the lice and fleas migrate from the cooling corpse, and the frequency with which they find their way to the warm body of the anatomist seems to show that their wandering is not aimless. The concealment of heat-radiation does not seem to have had any importance in the evolution of animals, but if the necessity should come to pass, a character already exists which could be turned to advantage.

I am not certain that this accidental radiation of heat has ever become useful to animals, in the fashion in which the production of light, a parallel side issue of oxidation, has been turned to account in many groups. I say I am not certain, for I remember that heat-radiation plays a part in the relations between young warm-blooded animals and their parents, and possibly in the relations of gregarious creatures. Long after the heat of the mother has ceased to be necessary to the feeble young, it remains an attraction. Those who have had experience in the rearing and taming of young birds and mammals know how fond these are of heat, and how readily they will find their way and attach themselves to non-luminous sources of heat, such as the human body, the warm corner of a room, or the surface of a radiator. Successive mammalian pets of my own, belonging to different groups, have selected the same corner of my dressing-room, where hot-water pipes emerge for a few inches on their way to a bath-room, and have picked out the same ways of getting to the same radiators. Warmth is a surer attraction to a young mammal than food, and if at any time it should become more important to the survival of animals that they should have additional means of finding their mothers, heat-radiation and the incipient heat-sense are ready to be used.

A few hours before I began to write these words (on a hot day in August) my attention was attracted by brilliant points of light in a flower-bed in the Zoological Gardens. It was too late in the day and too hot for dew-drops, and the points sparkled with an acuter, more coloured scintillation, like diamonds of the finest water. I found the source in the ripe blooms of a Solanaceous plant (*Salpiglossis emperor*). The tip of the style was a cross-piece like the arm of a crutch, and its upper surface bore a narrow, elongated, and deeply-grooved stigma. The sticky exudation formed a brilliant mirror in the hollow of the groove, and the curvature of the surface was such that the reflection of the sun met the eye as a single, acutely shining point of light. I have never seen anything more hardly brilliant in a living organism. The flowers were being visited by numbers of small flies; they emitted a sickly odour, and their colours were conspicuous. I watched for some time, but could not make out that the flies were attracted by the shining point, which indeed was visible only from a particular angle. They alighted on any part of the corolla and crawled indifferently over the inner surface of the flower. Here is a character, startlingly definite and conspicuous, and yet apparently only a side issue of the mechanical shape of the stigma and the production of the sticky juice. But if it should happen that diurnal insects exist which are attracted and dazzled by such a shining point of light, as we know that nocturnal insects are attracted by a source of light, a lure is there, appearing at the right moment and fully perfected.

We know that the emission of odours is frequently utilitarian. It is the chief means by which insects are attracted to flowers that bloom by night, and the plants scatter their perfumes on the air only when ripe for fertilisation. It is possible that the odours of the stem and leaves of many plants are distasteful to animals, and ward off their attacks. Among animals the emission of odours is the chief sexual lure and the awakener of the sexual reflexes, and no doubt it serves also to secure recognition between parents and offspring, and amongst the members of gregarious tribes. But there are many odours, just as definite and characteristic, which we cannot imagine to be useful. Almost every plant and the different tissues of a plant, almost every animal and the different tissues of an animal, can be recognised by the sense of smell. I may make a single example. In the course of anatomical work I have had to examine the digestive tract of many hundreds of birds, belonging to practically every group. It is a curious and remarkable circumstance that the intestines offer scents, even to a nose not highly skilled, racially or individually, that are almost as characteristic of the families as are the patterns formed by the intestinal coils, blood-vessels, and mesenteries. The nature of the food, the processes of digestion, the varying kinds of putrefaction, all contribute to the result, but the product, so to speak, is accidental, and cannot be imagined to have any utility.

It is with regard to the colour and pattern of living things that the craving of the human mind for teleology has led to the greatest excesses. I do not wish to suggest that colour and pattern, and the combination of the two sometimes called colouration, are never useful. I have no doubt that they serve a purpose

in the interplay of the sexes, that they are useful in the various fashions described by Darwin, Poulton, and Abbot Thayer, and that they have played a large part in the success and failure of races. But I wish to remind you that they are inevitable outcrops of the structure and physiology of living organisms, and that, howsoever they may have been altered under the agency of natural selection and sexual selection, they must have existed and will exist so long as life endures.

Pattern is essentially a repetition of parts, and is the result of the mode of growth of organisms. A few scraps of tinsel and coloured glass placed in the well of a kaleidoscope form indefinitely varying patterns as the tube is revolved and they fall into different places. The geometrical patterns are formed by the reflections from a set of mirrors in the bottom of the tube, placed so as to multiply the images. If irregular holes be torn in a sheet of paper that has been doubled and redoubled, a symmetrical pattern is visible when the sheet is unfolded. Growth of tissues takes place by the multiplication of cells, cell-masses, organs, and parts of tissues and organs, for there is a physiological limit to increase in size of the different units of the body. Thus repetition patterns occur inevitably, producing the various kinds of symmetry, radial, concentric, metameric, antimeric, and so forth, which are characters of living things so conspicuous that even the untrained eye at once distinguishes a fossil in the rocks or a shell on the sand from its contrast with the formless monotony of surrounding matter.

The multiplication or repetition of cells or parts may take place regularly, radiating in every direction from the growing point, until the product of one centre of growth is modified by the different conditions it meets on different parts of its periphery, by interference with the products of other centres of growth, or by the changed conditions of nutrition brought about by its own growth. Growth in one plane or radius may be arrested, in others proceed with greater vigour; so that annual systems spread out into curving streaks, like the stream-lines on the surface of muddy water, or it may be subjected to local, temporary, or seasonal intermittences, with a consequent elaboration of pattern. In its finest details and its gross structure every organism displays pattern.

When the microscope reveals the exquisite sculpturing on the surface of a scale, the graceful details of the cross-section of a stem, or the intimate beauty of tissues like brain, or liver, or kidney, we are not tempted to explain the patterns on utilitarian principles. We propound no theory of mimicry, or of protection, or of sexual advertisement, but are content to accept their presence as an organic fact. But when the growth patterns reveal themselves on the surface as the markings on a shell, the stripes on a skin, or the vermiculations on a feather, the craving for teleology is aroused. I do not doubt but that these natural patterns have provided material for selection, but chiefly in the sense that they have been obliterated where they were visible. No assemblage of living animals shows externally visible growth-pattern in a more conspicuous fashion than the members of the abyssal fauna, where the only light is a dim and fitful phosphorescence, and where conspicuousness can be attended with no disadvantage.

Organisms, like all visible things, must have colour, and it is still less necessary than in the case of pattern to suppose that the colour as such subserves a useful purpose. We do not ask what advantage it is to one form of carbon that it should be black and opaque, to another that it should appear a crystal of the rainbow, why calomel should be white, mercuric iodide scarlet, or what gain it is to the sea that it should display its deepest azure when we are shivering under the blast of the mistral. Many of the most brilliant colours, the shifting metallic sheens, are the direct result of structure. The incident light is broken up when it is reflected from a sculptured surface, as in the case of the shining glow of a pearl, the inner face of a shell, and the shifting brilliance of a rifle-bird's throat, or by reflection from an opaque surface through a transparent layer, as when the swim-bladder or the sheath of a tendon display the shivering hues of a mirror of polished silver. The pearl grows as a disease of the tissues of the oyster, hidden away from light, not revealing itself until the animal, dredged up from the bottom of the sea, has rotted into a putrid mass. The internal tissues of every creature reveal a multitude of iridescent surfaces only when the dissecting knife

lets in the light. A still larger number of colours are due to pigments, blues and greens more rarely, reds, yellows, blacks and browns almost invariably. Perhaps in most cases the pigment has a direct physiological importance, as for instance, the red colour of the blood, due to the presence of hæmoglobin, the substance that carries oxygen to the tissues, or the green chlorophyll of plants by which the radiant energy of sunlight is captured. Others are by-products of excretion, poisonous waste that has to be removed, like the brilliant derivatives of bile and urea. Extreme instances of the casual or accidental production of colour may be seen in the crimson of turacos, which is not merely a pigment, but one that is soluble in rain-water. The Malay tapir exudes a black sweat, and that of the hippopotamus is carmine-coloured. Still more suggestive is it to reflect that not only the visible surface of the body may be resplendent with vivid hues. The blood runs as red under the thick and hairy hide of an ape as on the fair cheek of a girl. Splashes and streaks of black, glows of yellow and green and scarlet, vivid contrasts of colour, diversify the internal organs and tissues, where they can delight the eye only of the anatomist, who, after all, is a small part of the economy of Nature. Ruskin once said that it was immoral if the back of a column, destined to be invisible to every eye from the moment it was put in place until the cathedral crumbled, were not carved as fairly and lovingly as the side that was to confront the world. In her dispersal of colour Nature is of the school of Ruskin, and no parsimonious utilitarian, scamping the invisible part of her work. Colour is lavished freely on creatures that rejoice in the sun and that seem consciously to flaunt their brilliance or coyly to match their surroundings, but it is lavished no less freely on internal parasites, creatures of the night, inhabitants of clefts in the rocks, or of the dim abysses of the ocean.

Colouration (the combination of colour and pattern) is in a sense accidental. A thin slice of almost any living tissue placed under the microscope reveals little of its structure because of the uniform grey of protoplasm. The skilled microscopist stains his sections, and as the different parts react differently, the uniformity disappears and the structure becomes visible. In the same fashion, in the laboratory of Nature colour often magnifies or intensifies pattern. Differences in texture of the component parts of the structural pattern may reflect light differently, so that iridescent hues map out the lines of growth. The bright exudations of the body reveal differences in the texture and substance of the tissues they reach, or the structural distribution of blood is made visible by the scarlet hæmoglobin. The combined effect is so conspicuous that we deem it must have a purpose. It is curious, however, to note how much inconspicuous pattern exists amongst animals and plants. The black variety of leopards and jaguars is a familiar instance; it is just possible to see, like a faint water-mark, the characteristic rosettes of the leopard or the jaguar on the uniform black fur. It may be said that these melanistic forms are abnormal, almost pathological; but there are many cases for which no such explanation can be offered. The young of almost all the cats, great and small, are spotted or striped, even if the adults are self-coloured. The kittens of cheetahs, or hunting-leopards, appear to be a remarkable exception, for, although the yellow fur of the adult is thickly set with black spots, the young are clothed with soft fur of a uniform pale grey; but closer examination shows that the under fur is spotted. Ray Lankester has called attention to the almost invisible pattern of stripes on the face of the young giraffe. The cony or hyrax is really a striped animal; when the creature is alive one can see in appropriate light that the hair is set in hoop-like bands running downwards from the dorsal middle line, but the uniform colouration masks this arrangement. I have almost no doubt but that the African rhinoceros is similarly a striped creature, the stripes appearing as structure and not as colouration.

The striped pattern of zebras is a salient instance of the combination of structure and colour, and there is excellent reason to suppose that it has been turned to a utilitarian purpose, and helps to protect the animal by making it less visible against a background, or merely by breaking up its outline and so making it less like an animal. But it passes belief to suppose that the different types of pattern found in Grevy's zebra, the Mountain zebra, and Burchell's zebra have different and appropriate utilities. They are the outcrop of different

structure, of similar, but not identical, material. The fate of the zebra-pattern in hybrids shows that structure, and not utility, is at the root of the matter. When a zebra is crossed with a donkey the hybrid has a smaller number of stripes, but these are very vividly marked, one along the dorsal middle line, one or two on the shoulder, and many on the legs. When it is crossed with a horse the hybrid is much more fully striped than the zebra parent, but the stripes are faint, almost invisible. Nor can it be supposed that the patterns characteristic of the different races or species of giraffe have separate utilities, although each of them may serve equally for protective concealment.

Although colour and pattern may combine to produce a result, the colour differences accentuating the structural differences, it frequently happens that the outlines of colour and pattern do not conform. In such cases the separate factors produce a result that is in a sense accidental, and that, although it may be useful, cannot have been produced because it was useful. Ruskin, who was an acute observer of natural objects, called attention to this in his chapter 'The Lamp of Beauty' in 'The Seven Lamps of Architecture.' 'I am quite sure,' he wrote, 'that any person familiar with natural objects will never be surprised at any appearance of care or finish in them. That is the condition of the universe. But there is cause both for surprise and inquiry whenever we see anything like carelessness or incompletion; that is not a common condition; it must be one appointed for some singular purpose. I believe that such surprise will be forcibly felt by anyone who, after carefully studying the lines of some variegated organic form, will set himself to copy with similar diligence those of its colours. The boundaries of the forms he will assuredly, whatever the object, have found drawn with a delicacy and precision which no human hand can follow. Those of its colours he will find in many cases, though governed by a certain rude symmetry, yet irregular, blotched, imperfect, liable to all kinds of accidents, and awkwardnesses. Look at the tracery of the lines on a camp shell, and see how oddly and awkwardly its tents are pitched. It is not, indeed, always so; there is occasionally, as in the eye of a peacock's plume, an apparent precision, but still a precision far inferior to that of the drawing of the filaments which bear that lovely stain; and in the plurality of cases a degree of looseness and variation, and still more singularly, of harshness and violence in arrangement, is admitted in colour which would be monstrous in form. Observe the difference in the precision of a fish's scales and of the spots on them.'

Analysis of the differences noted by Ruskin would probably show that when there was a coincidence of colour-outline with pattern-outline, the colour was fundamentally structural in character, that is to say either the result of interference and reflections, or of chemical differences in the different parts. In so far, the colouration would be in a sense accidental, a secondary result of the pattern. When the colour does not conform with structural lines, it is most often pigmentary, an exudation of the products of excretion staining the surface according to the osmotic conditions, or the relation of the internal organs to the external covering. Here again the total result of pattern and colour is still more accidental, due to uncorrelated factors. The work of the most modern school of painting, with its display of startling primary colours, and its insistence on masses rather than on outlines, is training us (in a fashion that doubtless would have been most repugnant to Ruskin, and that he would have denounced in language as vivid as a canvas of Matisse) to see beauty in combinations that we have been accustomed to regard as incongruous, and to comprehend harmony and design without the aid of the familiar scaffolding of outline and perspective. I admit in the fullest way that Nature may be a better guide than our acquired prepossessions, and that colour may show its highest value when it is divorced from form. I wish only to remind you that pattern is an inevitable outcrop of structure; that there must be colour, and that there must be combinations of colour and pattern. The living world, even if selection had played no part in moulding it, would still be a shining wonder, infinitely diversified.

In the two groups of the animal kingdom with which I am most familiar, there seems to be a general process, rather different in the two cases, according to which the evolution of colouration has taken place. In each case there has been a transition from patterns that are the plain consequence of growth.

forces, such as the simple geometrical markings which are structure revealed, through more irregular stripes and blotches, which may be set down to irregular growth, first to a uniform colouration which obliterates the structural form, and lastly to odd and brilliant disguises of the true contours of the body. I do not doubt but that natural selection has attended each stage of the process, now rejecting and now favouring the patterns that have emerged from the laboratory of nature, as they turned out to be harmful or useful.

Comparison of the lower and higher groups of mammals and of the earlier and later stages of individuals would appear to lead to the inference that primitive mammals were spotted or striped. Spots and stripes become increasingly frequent as we pass from the higher to the lower groups. If the adults are spotted, the young are, I believe, always spotted; if the adults are striped, the young are always either spotted or striped; when the adults are self-coloured, or when they display the strange markings which conform with none of the structural lines of the body, and which Abbot Thayer has interpreted as 'ruptive' or outline-breaking, the young are striped, spotted, or uniform.

Man and his allies, the apes, monkeys, and lemurs, compose what we must regard as the highest group of mammals, and among them stripes and spots are extremely rare in the adult or in the young, the most obvious cases being the rings on the tails of lemurs. The tiger, leopard, jaguar, and cheetah are familiar instances of striped and spotted carnivores, and their young are always striped or spotted. But the young of the self-coloured lion, puma, and caracal are spotted, and lynxes, which are greyish-brown in the adult summer coat, are brilliantly spotted with black when young. Small carnivores such as civets and genets, binturong and ichneumons, have many striped and spotted forms, and here, again, the young of the striped and spotted creatures are always striped or spotted, and the young of the self-coloured animals are not infrequently striped or spotted. Antelopes are not often striped or spotted, but the banded duiker, which is marked with hoops across the back, has young with a similar pattern. The South African eland shows almost no traces of striping when it is adult, but the calves have barrel-like hoops of white, and in the Derbian eland and the kudus, where the stripes persist through life, the young have them more strongly marked. Sitatunga antelopes are nearly devoid of stripes in the adult condition, but their young are brightly striped and spotted. The bongo and angas antelopes and the beautiful harnessed antelopes are striped, although the stripes tend to disappear in old bulls, and their young are vividly striped. The young of a large majority of different kinds of deer are spotted; sometimes the spots are retained throughout life; sometimes they are found only in the brighter coats of summer, sometimes they disappear altogether. But I do not know of any spotted deer with self-coloured young. The young of true wild swine, pygmy hogs, river-hogs, and wart-hogs are marked with longitudinal stripes that disappear in the adult. The young of the American and Malay tapirs are striped and spotted. Spots, dapplings, and stripes are more common in foals than in adult horses and asses. The foals of all the zebras are vividly striped, and there seems reason to believe that the less striped forms are the descendants of forms that were more fully marked. Among the rodents many are marked with stripes or with spots arranged in longitudinal rows, and the young of the striped forms are always striped. A good many marsupials are spotted or striped, and precisely the same condition obtains; the young of the striped or spotted animals are always striped or spotted.

The suggestion was made many years ago, I think first by Dr. Bonavia, that these spots and dapplings, so frequent and so plainly ancestral, were legacies of a primitive coating of scales like the armour of armadillos and of their gigantic extinct allies, and it is at least a fair speculation that they are to be associated with the scaly covering of the reptilian ancestors of mammals. Without pushing the argument to this extreme, we may at least assume that the presence of spots, reticulations, and stripes (the latter being expanded spots or fused rows of spots) are indications or revelations of the composite nature of the skin, which is not merely a uniform sheet stretched over the surface of the body, but a structure growing from many centres. Like the cranial and spinal nerves, these centres were no doubt fundamentally segmental in character, but

by unequal growth, areas belonging to one segment occasionally have invaded neighbouring territory, and the primitive regularity has become disguised, and tends to be more and more disguised in the course of ontogeny and phylogeny. In such anatomical and physiological facts we must seek for the origin of the primitive patterns of mammals. No doubt in many cases they have been retained and perhaps accentuated by selection. But selection does not and cannot account for their origin. It seems to me in many cases incredible that they are utilitarian. In the young of many animals, they may serve for protective concealment, but they occur almost with equal frequency on the least visible portions of the body, on the under parts and legs, and in the case of creatures whose young are carefully hidden and sedulously guarded by the parents. The general trend of events seems to be the obliteration of these primitive patterns, and their replacement by an even tone. The even tone, in its turn, is being replaced, especially in the males, by countershading, and by many of the odd and brilliant patches and marks which may be interpreted as decorative sexual colouration or as ruptive, outline-breaking patterns. Where the young are neither striped nor spotted they are more uniformly coloured than the adults, and slowly acquire the adult condition, the females more slowly than the males.

The trend of events in birds is similar but not identical. The kind of plumage most common in the lower types of birds and that appears most frequently in young birds is a rather uniform dull brown or grey, marked with patterns of stripes and spots and mottlings symmetrically arranged with regard to the whole body and to the individual feathers. Many of these primitive patterns and colourations suggest the accidental expression of structure, and can be imitated in a very close fashion by mechanical means. Certainly they appear to serve for protection, and blend with rough and mottled backgrounds in a very complete fashion. But, just as in the case of mammals, they often occur on parts of the body not naturally the most exposed, or in cases where protection is secured by other means. At first the plumages of the young and of adult males and females were similar and retained throughout the year. Next, during the breeding season, the males began to assume brighter colours, and when the breeding season was over, relapsed into the duller ancestral plumage, passing into the condition usually spoken of as 'eclipse.' In such a stage, the males in eclipse, the females and the young were all much alike, and there are many birds in which this condition is retained. A later modification came about when the females as well as the males began to assume brighter tints in the breeding season. When the breeding season was over, males and females both went into eclipse, with the result that males and females in eclipse, and the young in their early plumage, were all much alike, and wore a plumage recalling the ancestral condition. This stage persists in a large number of cases. Then the period during which the breeding plumage was retained became longer and longer, half the year in some of the weaver birds, for all but a few weeks in the game birds and in most of the ducks, or for the whole year, as in South American ducks, kingfishers, and parrots. Every stage in the suppression of the eclipse or ancestral plumage still exists; in some of the game birds and tanagers, for instance, it is represented only by a few feathers. When the eclipse plumage has been suppressed, only the young birds retain the dull ancestral livery, and there are many cases in which even the newly fledged birds, or birds in the first down, show traces of their future brilliancy.

I have attempted not to weary you by going into much detail. I have been trying to show you that amongst birds and mammals there has been a general change from dull colours and mechanical patterns to brilliant and fantastic garbs, an intermediate stage of almost uniform colouration having been passed through. The process has been an inevitable outcrop of organic growth, a naive blossom of the tree of life, as free from purpose as art is free from morality. It has been associated with an increase in the vigour of the body and a heightening of the vital activities, so that growth, respiration, and excretion, and all the chemical changes in the living laboratory, have become more exuberant. It is natural, therefore, to find the beginnings of more brilliant colour and more aberrant growth associated with the breeding season, for it is then that the strength and vigour of the animal body are most acute. No doubt there were critical stages during which natural selection played a great part; most notably

the suppression of the primitive geometrical growth patterns which are most abundant in situations where they are least seen, more abundant in young creatures than in adults, and in lower groups than in higher groups. The later stages, in which dull uniformity has been replaced by exuberance of colour and extravagance of form, may have secondary utilities either as stimulants to sexual activity, acting through the organs of sense, or from the fashion in which they disguise the natural outlines of the body. But I have tried to submit evidence that even if natural selection and sexual selection had not been at work, there still would have been a gradual increase in the fantastic beauty of the organic world, as growth became more complex and metabolism more active. At the least there is nothing more superfluous than to object to the theory of Darwin, that it cannot explain the existence of material for selection. The circumambient media, pressing on the obstinate living organism, mould it by processes of selection and rejection, but the material is there, a varied yet inevitable product of inherited structure and function. These are the

'Hierarchs and Kings
Who from their thrones pinnacled on the past
Sway the reluctant present.'

Sir George Fordham proposed and Mr. H. D. Acland (Royal Institution of Cornwall) seconded a hearty vote of thanks to the Chairman for his valuable address, which was carried.

Sir George Fordham, on being called on by the Chairman, outlined the arrangements which were being made by the French Association for the Advancement of Science, and the invitation from that body to the Conference of Delegates to hold their meeting next year at Havre during the meeting of the French Association. He said that the Conference must definitely settle now if it will accept the invitation. Although the British Association could not meet in a foreign country, there was nothing in the rules to prevent the Conference meeting where it wished. The Council of the Association had accepted the invitation of the French Association on behalf of any of its members who might like to attend the meeting at Havre. The wording of the section of the Report of the Council for 1912-13 relating to this matter is as follows:—

> (*d*) A letter has been received from Dr. A. Loir, of Havre, Local Secretary for the Meeting of the French Association for the Advancement of Science in Havre in 1914, intimating that the municipality of Havre desires to invite as guests leading Members of the British Association who do not attend the meeting in Australia, and that all Members not attending that meeting will be welcomed at the meeting of the French Association; also proposing that the Conference of Delegates should meet in Havre. Information has also been received from Dr. Loir that a Local Committee, including some of the principal British residents in Havre, has been formed for the reception of Members of the British Association.
>
> It was resolved that the invitation be cordially accepted, in general terms, and that details of the arrangements be left to the consideration of the President and General Officers and a committee appointed to assist them.

The opening meeting of the French Association will be held on August 4.

Dr. A. Loir, on the invitation of the Chairman, confirmed what Sir George Fordham had said about the invitation of the French Association to the Conference of Delegates, and said that the matter was being taken up enthusiastically by the City and Municipality of Havre.

Mr. G. C. Druce (Ashmolean Natural History Society of Oxfordshire) regretted that holding the Conference in Havre in August would prevent members going to Australia from attending it, which they would be able to do if the Conference was held in London in November, as was the case when the Association went to South Africa.

On the Chairman asking for a vote on the desirability of the Conference of Delegates meeting in Havre in 1914, it was proposed by Mr. John Hopkinson (Watford Camera Club) and seconded by Mr. A. W. Oke (Brighton and Hove Natural History and Philosophical Society) that the meetings of this Conference of Delegates be held next year at Havre on the occasion of the meeting

of the French Association for the Advancement of Science. To this Mr. H. D. Acland proposed an amendment that the Conference of Delegates should first meet in London and carry out a part of the business of the Conference and then adjourn to Havre. This was seconded by Mr. Bryan Corcoran (Croydon Natural History and Scientific Society). On being put to the vote the amendment was lost, eight voting in favour and fifteen against. No other amendment being brought forward, Mr. Hopkinson's proposal was put to the meeting and carried as a motion to be brought up at the meeting of the Committee of Recommendations by the Vice-Chairman of the Conference.

In the absence of the Rev. William Johnson, who was to open a discussion on 'The Relationship of Local Museums with Educational Institutions,' the Conference was adjourned to the 16th.

Mr. Johnson wrote later that an accident to his hand prevented him from attending the meeting of the Association.

Second Meeting, *Tuesday, September* 16.

In the absence of the Chairman the Vice-Chairman took the chair *ad interim*, the Corresponding Societies Committee being represented by the Rev. J. O. Bevan, Sir Edward Brabrook, Mr. W. P. D. Stebbing, and Mr. W. Mark Webb.

The Chairman reported that at the meeting of the Committee of Recommendations he had brought forward the Conference's resolution that it should hold its meetings next year at Havre, and that after discussion the matter had been referred to the General Committee.

The Rev. J. O. Bevan (Woolhope Naturalists' Field Club) thought that there might be an informal meeting of the Delegates in Australia, and that the official meetings might take place afterwards in London.

Mr. W. Mark Webb (Selborne Society), asking if there was any rule preventing the Conference from meeting in Australia, was informed that it met in Toronto on the occasion of the British Association's visit there in 1897.

Mr. H. D. Acland suggested that Delegates should be sent to Australia not to hold a Conference but to keep in touch with the work of the Association. He was hoping to go to Australia.

Mrs. Julian (Torquay Natural History Society) having spoken in agreement with the remarks of the last speaker, the meeting decided, on the motion of Mr. A. W. Oke, seconded by Mr. W. M. Webb, to proceed with the next business.

The following subject for discussion was brought forward by Mr. A. R. Horwood (Leicester Museum):—

Scientific Societies and the Control of Plant Extermination.

The resolution which this Conference passed last year relative to the aim (if not the work) of the Plant Protection Section of the Selborne Society has encouraged and stimulated the Section to further endeavours.

As a consequence an appeal was made to the scientific societies in this country to support the work in a definite way by the appointment of a corresponding secretary who might keep in touch with the Section and continuously advance the work *locally*, in the *special* way demanded by each district.

The necessity of some such method of decentralisation had long been apparent to the Section working from headquarters in London. It was felt impossible for the Committee, however large and energetic, to do what a body of willing and intelligent workers in each district might do locally. Indeed, the organisation of and correspondence with such a body of workers is in itself a large enough task, together with the planning of the *modus operandi* for securing the aims of the Section. For many reasons men on the spot with local knowledge and interest are essential to the success of this or any other widespread and far-reaching movement.

As a result of the appeal made to some 300 secretaries (though I have not full or final details as yet, as reports have to come in later from a large number of societies) nearly 100 corresponding secretaries have been or will be appointed.

As in the British Isles there are 117 counties (as defined by H. L. Watson, including vice-counties), one might be disposed to stop here, but since some counties have no efficient societies, whilst others, *e.g.*, Yorkshire, have a great

number, an endeavour has been made to appoint one secretary at least in every county, and in the case of counties not represented by any society the Section has appointed district secretaries in place of corresponding secretaries. But of the 117 counties I may say that between one-half and two-thirds are represented by a secretary in touch with us, a decidedly encouraging result. But this was not done at once; several appeals had to be made before a single reply was received, usually because of absence, of deferred meetings, &c., and nearly a thousand appeals were sent, involving various replies, to obtain this result.

To each corresponding secretary nominated by a Society, after application to the secretary, the following suggestions for local work were sent as a basis for his or her own active campaign :—

Suggestions for Local Societies.

It is suggested that your Society might possibly carry out the following programme as far as it can be adapted to local needs :—

1. Choose a member to act as a corresponding secretary who would keep in touch with the movement and report measures adopted, or instances of extinction.
2. Constitute itself a local body ready to :—
   - A. Inform the Recorder of any cases of extinction, with their causes, and send photographs of sites as well as definitely compare present records of the flora with earlier ones.
   - B. Educate the people locally by means of the Press as to the importance of plant protection.
   - C. Help to distribute information and display notices as to plant preservation (to be obtained from the Selborne Society).
   - D. Memorialise the County Council to obtain a local order for plant protection, and secure signatures to a petition for legislation (a Bill is being prepared).
   - E. Endeavour to create locally a public opinion against the too abundant collection of plants.
   - F. Work to obtain the purchase of tracts that need reserving, and discuss with the Selborne Society the formation of sanctuaries where needed.

A quarterly report should be sent as to facts ascertained (A and F), progress made (B–E), and help and advice needed.

In addition to such work, the Section proposes to obtain the help of the secretaries in obtaining data in each area as to the need for the reservation of any tract of land, or the protection of any particular plant. This will be in the nature of registration, as followed out in Prussia, and in exceptional cases exact maps of such areas may be required.

This is an era of land-inquiries, and as one of the most important aspects of plant-protection has to do with the estates of landowners, who as a body could help in the work of protection, and as much depredation is carried out upon their property, their assistance is to be sought in protecting plants, and it is proposed to ascertain who are the landowners in each district, the extent of their property, and so on. In this way, if local orders (as is hoped) become general, then the Section can lay down all the machinery necessary for the carrying out of protection without the creation of a single extra official, which is the only objection made to this method of preservation. The necessity for organisation is obvious.

Too great emphasis cannot be laid upon the great principle of co-operation, without which no work of this national character can be done. One is even led to suggest the federation of all such conserving bodies for common strength and unity. But the present attitude of harmony towards each other is all that can be expected so far, so diverse are the objects in view.

In this campaign one thing is of paramount importance, the necessity of promoting a public opinion upon the matter. Prevention is better than cure.

The deliberate efforts made towards the proper safeguarding of national monuments abroad must be the pattern by which we must work. Though much remains to be done in this country, yet much has already been done. There

must inevitably be divergent opinions as to how it is to be done, who is to do it, and so on, but these discussions surely do more good than harm.

And it is surely *the* work of scientific societies, since the material to be preserved is that upon which such bodies are continually engaged in research, and its conservation is a principle to which each society must subscribe.

I would ask that as practical a result of this discussion be arrived at as was achieved last year; that is, the unanimous voice of the Conference upon the desirability of organised effort.

With the approval of your Secretary and that of the Chairman of the Section, I submit to you a resolution, which I wish to have sent to every member of Parliament in the country through the corresponding secretaries or, in default, by the Section, asking them to approve the principle of State protection and the framing of a Wild Flowers Protection Act.

> [1] ['That this meeting of the Delegates of Scientific Societies gathered in Conference at the meeting of the British Association for the Advancement of Science at Birmingham, September 16, 1913, records its opinion that the time has arrived when the question of the protection and preservation of wild plants demands the attention of Parliament] by the appointment of a Commission to recommend the enactment and endowment of such a measure by the State, and the passing of an Act to make and enforce regulations required.'

It is proposed to get each secretary to send a copy of this resolution with Leaflet No. 1 to his M.P., with a request for a reply and an expression of opinion.

These replies would be collected by the Section, and a definite estimate formed of the possibility of success and the best means of attaining it.

Meanwhile, the work of the Section will be to collect data which will serve, when a Commission is appointed or a measure brought forward, to provide reasons for its promotion. This method is calculated to save delay.

The CHAIRMAN, speaking on the resolution suggested by Mr. Horwood, thought that it was rather cumbrous and that it would be almost impossible to get a Royal Commission appointed.

After discussion on Mr. Horwood's resolution by Sir Daniel Morris (Bournemouth Natural Science Society) and Mr. Joseph Wilson (Essex Field Club), Mr. WILSON proposed an amendment to the resolution that all the words from 'Parliament' to the end be omitted. This was seconded and carried.

Mr. T. SHEPPARD (Hull Scientific and Field Naturalists' Club) said that he was not sure from what benighted parts of the country the various delegates present might have come, but he could assure them that in the North they were sufficiently civilised to look after their botanical treasures without such drastic measures being taken. The Yorkshire Naturalists' Union, with its forty affiliated societies, and nearly 4,000 members and associates, had for many years taken the greatest possible interest in the preservation of the flora and fauna of the county, some of the more interesting localities being protected by watchers paid from the Union's funds. Nor did they, in Yorkshire, find that serious harm was done, either by collectors or herbalists. After many years' work he felt that in Yorkshire, and surely in other parts of England as well, the various societies were doing much more good in looking after their floral treasures than harm in collecting them. In fact, he felt that the professional or amateur 'collector' was an exceedingly rare individual; one reason being his difficulty in disposing of large quantities to advantage. He was sure that Yorkshire botanists would resent any action being taken which would interfere with the present very satisfactory state of things.

He also resented interfering in any way with the landowners, either by making suggestions to them or by giving them additional powers. From many years' experience with landowners (as secretary to his society) in all parts of Yorkshire, he had found that they were invariably willing to give every facility to natural history societies to roam over their estates, and he believed that during the very many years in which this privilege has been given to Yorkshire naturalists, on seven or eight occasions each year, there had not been

[1] The resolution carried is put in square brackets.

a single instance in which the privilege had been abused. In the suggested powers that it was proposed through Parliament to give he saw grave danger of this present state of things being interfered with.

In other respects, the suggestions now made had already been adopted by several societies many years ago.

He also, as representative of one of the largest societies in the Union, resented the suggestion that all these various societies should come under the wing of the Selborne Society in this so-called protective scheme. He did not wish to deprecate in any way the excellent work the Selborne Society was doing, but he felt sure that many societies whose delegates were present felt that they were able to continue the work they had been doing for many years without being connected with the Selborne, or any other society of that kind.

Mr. William West (Bradford Natural History and Microscopical Society), as an ex-President of the Yorkshire Naturalists' Union, endorsed all Mr. Sheppard's remarks. The less said in calling attention to rare plants the better; it simply calls the attention of both vandals and collectors to the desirability in their own interests of collecting these plants for sale or other purposes. A true naturalist would never buy a rare specimen if there were the slightest chance of its extinction.

The discussion was at this point adjourned until the following subject had been brought forward by Mr. R. H. Whitehouse.

The Best Means of Preventing the Extinction of Local Species.

It is an easy matter to talk about what measures should be taken to prevent the extinction of species, but it is exceedingly difficult to find really practicable measures to enforce.

This subject has occupied the attention of the Belfast Naturalists' Field Club for many years; not so much for the necessity for active measures in their district, for we are singularly free from the wanton destruction reported from many districts, but more from the fact that they realise that it is better to have some workable scheme in readiness should necessity arise. Besides, the Club is anxious to do its part for the common good, and to support heartily schemes which will prove effective in preserving local species from destruction.

Discussion will be most profitable if we place ourselves in the position of the people who would be affected by any measures; we shall then be in a better position to realise the objection to schemes.

We must not forget there is a dominant characteristic of the British public which all reformers do well to consider, namely, the resentment to interference with what are thought to be personal liberties.

There are some causes for extinction over which, apparently, we have no control; I am thinking of 'progressive schemes' chiefly associated with the extension of towns. As a town expands (and here in Birmingham we know what that means) people penetrate further into the country for recreation. The chief occupation of our lower artisan classes during their country-rambles to-day is to make 'short cuts,' cut sticks from hedges with which to mow down any herb that is handy, remove ferns, saxifrages, &c., from walls and carry on other such acts of destruction. I cannot see any really practical means which can be adopted in this country against this evil; in Germany they would simply erect a prohibitory notice and nobody would go! And I might add that, as a lover of Nature, I strongly resented such notices even when in Germany. The average Britisher resents notices against trespassing, and I know naturalists who even make it a rule to invade all fields and woods which are forbidden.

The construction of public works is another frequent cause of destruction to objects of natural interest. The construction of huge reservoirs, as in the Lake District and Elan Valley, is fatal. Drainage schemes similarly affect certain species. The construction of a railway is frequently attended with disasters, as we so frequently see in Sutton Park, where fires are common during hot weather, and are caused by hot cinders as often as by carelessness of the public.

What I want you to realise is that as naturalists we are of second-rate importance against such destruction. Many enthusiastic lovers of Nature talk as though rare animals and plants were of the first importance. This is a

commendable enthusiasm, but it is sometimes a blind one. Areas *must* be drained; reservoirs *must* be made; railways *must* be constructed. When all is said and done, economic matters have, and always will have, greater weight than natural history matters. We must give way and mourn the loss of our valued friends.

I emphasise this side of the question because I know abler men than I will deal with preventable cases. But it seems to me that even here we need not be idle. Probably in the case of economic advances, the best means of preserving species liable to destruction would be some such method as the following: Our natural history societies should be provided with a complete list of the fauna and flora of their districts; they should make themselves acquainted with all schemes which involve the destruction of any species, and attempt to preserve them by such means as transplanting as nearly in the same district as possible.

In such discussions as these, it frequently happens that much time is spent in denouncing the actions of certain people in ruthless collecting; I am fully aware of such disgraceful vandalism, but at the same time I feel that we should be careful to see that we do not anger any class by hasty accusations. One person who is always accused is the teacher of nature-study with his class of pupils. To some teachers a plant has no interest unless it be rare in the locality; so one of the first things to try and bring home to all such teachers is that the commonest plants are of equal educational value to rare ones.

I have had some considerable experience of teachers of nature-study, and in spite of the accusations that have been made, I must put in a defence for them. Teachers are either well-informed naturalists or only superficially acquainted with animals and plants. In the former case, I have found that, being well acquainted with the rarer forms, they have been the very first to take special pains to preserve them from destruction; in fact, they are the people I look to for assistance in any reforms we may suggest. In the latter case, I know, we have unfortunate offenders, but there are many reasons why the damage done is not so great as many would have us believe. For example, such teachers seldom pass beyond the most frequented lanes, and very little precious stuff grows in such places; again, their very limited knowledge restricts them to the commonest plants; no wideawake teacher will invite difficulties by attracting the attention of his scholars to a plant he knows nothing about. Examine the collections of children, and you almost invariably find that they consist of common plants. Classes of children have been seen in Sutton Park, each child of which had a whole specimen of the butterwort, with the result that the area visited was quite cleared of this plant. This is an unfortunate instance only too true, but I venture to suggest it is not a common practice. It so happens that insectivorous plants have a great attraction for those who draw up school-curricula; we do not wish to prohibit instruction on these plants, but to do something to prevent their removal.

Another unwelcome character is the professional collector; where money is a consideration, the instinct to preserve rareties is liable to be suppressed. But where does the fault lie? Surely with the purchaser. Much as we might dislike acknowledging it, it is the places of higher learning that are primarily responsible. As university-teachers we require and buy these precious species, and so the professional collector makes his money and exterminates them. Yet I know collectors who are most careful not to remove such species entirely; probably also from the business point of view, for it is advisable to keep a supply! What is the remedy? Why should not the natural history societies take the matter up? If, as I have suggested, each natural history society provided itself with a list of the fauna and flora of its district, and undertook to supply material, the work might be transferred from the ruthless money-maker to interested societies; at any rate a sufficient check would be placed on supplies to prevent total extinction.

Of course the difficulties are great, and we must decide whether or not they are insurmountable. Naturalists are often bad business men, and from my experience I would say a professor would perhaps be surer of his stock from the professional collector. Another thing, the professional collector is usually a member of the local natural history society, and a valuable member too. So the difficulties increase.

Let me touch on the view of those who advise education as the cure. I confess I do not see much hope there yet. In fact, if it is 'prevention of extinction with no risks' that is aimed at, no education at all would be the safest course.

It is a very high standard of education that is required to make a person appreciate the value of rarities in the animal and plant worlds. In our schools, it is better to omit instruction on uncommon forms; the commonest things in Nature are sufficient for a general education. It is the university—and college—student to whom we should appeal to respect rarer forms, and it may be worth while to make such an appeal; for rare creatures usually have only an academic interest.

The natural history societies should draw up the fauna and flora lists, and call the attention of headmasters and nature-study teachers to the desire to preserve certain species growing in the district; there need be no indication in the appeal as to where such plants grow.

Many societies already have such lists. Probably no place is more accurately worked than the North of Ireland, and it would not be a formidable task to single out examples for presentation to teachers of nature-study.

Much valuable assistance against ignorant destruction of rarer species might be obtained from the Press. Many of our 'dailies' give special columns to 'Nature,' and the rarer forms are objects for special description. If we make an appeal to the Press to emphasise the desirability of cultivating a pride in our local fauna and flora, such an appeal may be attended with success.

I see no other means of preventing the extinction of local species; it is a moral claim we have to make, and that is always the most difficult to establish.

My remarks have frequently tended to be in the direction of a plea for the defendant. I have taken this course deliberately in order that those who are prepared to present schemes for the prevention of destruction of local species may perhaps be in a better position (1) to realise the kind of opposition which offenders will raise against any measures which tend to limit a continuance of their practices, and (2) to form less hasty judgments on those who are considered offenders, traditionally, at any rate.

The CHAIRMAN, to show the position of affairs, read the following resolution from Section D, and the Council's motion on it:—

> 'That the British Association for the Advancement of Science deplores the rapid destruction of flora and fauna throughout the world, and regards it as an urgent duty that immediate steps should be taken to secure the preservation of all species of animals and plants, irrespective of their economic or sporting value.'

The Council approved the principle of the above resolution, and resolved to give expression to it in the following terms:—

> 'That the British Association for the Advancement of Science deplores the rapid destruction of fauna and flora throughout the world, and regards it as an urgent duty that steps should be taken, by the formation of suitably placed reserves or otherwise, to secure the preservation of examples of all species of animals and plants, irrespective of their economic or sporting value, except in cases where it has been clearly proved that the preservation of particular organisms, even in restricted numbers or places, is a menace to human welfare.'

Sir EDWARD BRABROOK (Balham and District Antiquarian and Natural History Society) said that this resolution of the Council embodied a resolution passed by the Conference of Delegates at Dundee and sent up to the Council.

Continuing the discussion on the two papers which had been read, Mr. W. MARK WEBB (Selborne Society) said that his society did not wish to depreciate or supersede the work of any other. The section devoted to plant protection only looked for help and co-operation in its undertakings. He thought that the power of the law should be definitely behind those who wished to preserve certain plants on their estates. He gave instances of extermination and damage in a particular case. He also alluded to the good work which had been done by nature-study teachers by inculcating respect for living things, and agreed that common objects were better teaching material than rare ones, although there was much wilful destruction of common plants.

The Rev. FREDERICK SMITH (Prehistoric Society of East Anglia) said, in criticising the 'utility' standpoint of Mr. Whitehouse, that so far from accepting such a position, the fact of the constant encroachment, owing to the exigencies of modern ways, upon the freedom of our native fauna and flora is the very reason why we, as students and lovers of Nature, should be more and more earnest and anxious for their defence and protection. We can do much toward helping to extend the areas of rarer plants by planting seed in likely places. This was a common practice of the speaker's friend, the late Dr. Buchanan White, of Perth. Some now very rare plants were once common in his society's area; and now common species may become rare in their turn. There is something touching and wise in the Eastern view that it is a sin to destroy any life that only a God could give. It is assuredly a greater misdeed to allow, if it can be prevented, the annihilation of a single species of any kind of animal or plant.

Another delegate thought that Mr. Horwood's work was not on the right lines, and could not tolerate Mr. Webb's suggestion that landowners should be given power to prosecute for the taking of wild plants. He agreed with the resolution passed in Section K, that there should be no change in the law of trespass. He gave instances of German regulations and methods of protection, which he considered inapplicable to Britain. The artificial dissemination of the seeds of wild plants, he thought, was against all work on their natural distribution.

Mr. BRYAN CORCORAN (Croydon Natural History and Scientific Society), while against the idea of a new Act of Parliament for plant-protection, approved of much in Mr. Whitehouse's paper. He thought that Herbert Spencer said something to the effect that when an Act of Parliament was passed to protect any special section of the community that very section soon began to suffer. He believed that an Act as suggested would be very likely to aggravate the trouble it was passed to prevent. He asked if it would be possible to cultivate rare species away from their habitat, advertise them in the 'Selborne Magazine,' and make it worth while for dealers to sell them from these nurseries?

Professor J. H. PRIESTLEY (Leeds Naturalists' Club and Scientific Association) asked delegates to remember that the debate had shown that there was little agreement as to any line of action more extended than that covered by the previous resolution of the Council of the Association. That resolution recognised the urgency and importance of the problem, and recommended constructive proposals on the line of Nature reserves. This discussion made it clear that it was unwise without further consideration to press the matter upon the attention of the public with a view to legislative action. He therefore moved: 'That the previous question be now put.' This, having been seconded, was carried.

In consideration of the motion just passed, Mr. JOSEPH WILSON asked leave to withdraw the amendment which stood in his name. This was agreed to.

The CHAIRMAN having read Mr. Horwood's resolution, Sir DANIEL MORRIS asked what was the present position, and was informed that there was no resolution to go before the General Committee.

The CHAIRMAN drew the attention of the Conference to fresh evidence which it was desired to gather regarding the working of the Wild Birds Protection Acts and the damage done by certain birds, such as the wild pigeon. It was suggested that evidence should be heard before a Departmental Committee. He proposed the following resolution: 'That it be referred to the Corresponding Societies Committee to arrange for evidence being given before the Committee which, it is understood, is about to be appointed by the Home Secretary to consider the amendment of the Wild Birds Protection Acts.'

This having been seconded by Mr. H. D. Acland, Mr. WEBB pointed out that if the Plumage Bill then before Parliament became law only ostrich feathers and eider down could be imported, and that the additional powers to be given to the Home Secretary might be intended to check the use of the plumage of native birds for commercial purposes.

The resolution, having been put to the meeting, was carried.

Mr. H. D. ACLAND moved the following resolution: 'That this Conference hears with regret that the work of the Royal Cornwall Polytechnic Society has

been curtailed in consequence of the magnetic observatory of the Society coming to an end.'

He explained that the observatory at Falmouth had been discontinued in consequence of the establishment of the observatory at Eskdale Moor and the withdrawal of the grants from the Royal Society and the British Association. It was a misfortune that such highly scientific work as had been carried on continuously by this Society should be discontinued. It was important that the British Association should know that this Conference regrets the discontinuance of the work of one of its affiliated societies. To that end the resolution should be sent to the Council.

The Rev. J. O. Bevan seconded the resolution, which was then carried unanimously.

The following Delegates attended the Conference and signed the attendance book, their attendance being indicated by the figures 1 and 2, which refer respectively to the first and second meeting.

AFFILIATED SOCIETIES.

1 2	Andersonian Naturalists' Society	M. A. B. Gilmour, F.Z.S.
1	Ashmolean Natural History Society of Oxfordshire	G. Claridge Druce, M.A.
1 2	Belfast Natural History and Philosophical Society	Dr. Allworthy.
1 2	Belfast Naturalists' Field Club	R. H. Whitehouse, M.Sc.
1 2	Berwickshire Naturalists' Club	G. P. Hughes, J.P.
1	Birmingham and Midland Institute Scientific Society	C. J. Woodward, B.Sc.
1 2	Bournemouth Natural Science Society	Sir Daniel Morris, K.C.M.G.
1 2	Brighton and Hove Natural History and Philosophical Society	Alfred W. Oke, F.G.S.
1	Burton-on-Trent Natural History and Archæological Society	Dr. Stern.
1	Cardiff Naturalists' Society	Prof. E. P. Perman, D.Sc.
1 2	Cornwall, Royal Institution of	H. D. Acland, F.G.S.
1 2	Cornwall Royal Polytechnic Society	H. D. Acland, F.G.S.
1 2	Croydon Natural History and Scientific Society	Bryan Corcoran.
1	Dorset Natural History and Antiquarian Field Club	Alfred Pope, F.S.A.
1 2	East Anglia, Prehistoric Society of	Rev. F. Smith.
1 2	Edinburgh Field Naturalists' and Microscopical Society	W. C. Crawford, F.R.S.E.
1 2	Edinburgh Geological Society	R. C. Millar.
1 2	Essex Field Club	Joseph Wilson.
1	Glasgow Royal Philosophical Society	Prof. James Muir, D.Sc.
1 2	Hampshire Field Club and Archæological Society	W. Dale, F.S.A.
1	Hampstead Scientific Society	C. O. Bartrum, B.Sc.
1 2	Hertfordshire Natural History Society and Field Club	Sir George Fordham.
1 2	Holmesdale Natural History Club	Miss M. C. Crosfield.
2	Hull Geological Society	T. Sheppard, F.G.S.
2	Hull Scientific and Field Naturalists' Club	T. Sheppard, F.G.S.
1 2	Isle of Man Natural History and Antiquarian Society	W. H. Patterson, M.Sc.
1	Liverpool Geological Society	J. H. Milton, F.G.S.
1 2	London: Quekett Microscopical Club	G. F. Rousselet.
1 2	London: Selborne Society	W. Mark Webb, F.L.S.
2	Manchester Geological and Mining Society	William Watts, F.G.S.
1 2	Norfolk and Norwich Naturalists' Society	Miss A. M. Geldart.
1	North of England Institute of Mining and Mechanical Engineers	Hugh Johnstone.
1 2	North Staffordshire Field Club	W. Wells Bladen.
1	Northamptonshire Natural History Society and Field Club	C. A. Markham, F.S.A.

1 2	Northumberland, Durham, and Newcastle-on-Tyne Natural History Society	R. S. Bagnall, F.L.S.
1 2	Nottingham Naturalists' Society	Prof. J. W. Carr, M.A.
1 2	Rochdale Literary and Scientific Society	J. R. Ashworth, D.Sc.
1 2	Sheffield Naturalists' Club	Wm. Parkin, F.R.M.S.
1 2	South-Eastern Union of Scientific Societies	W. Dale, F.S.A.
1 2	Torquay Natural History Society	Mrs. Forbes Julian.
1 2	Vale of Derwent Naturalists' Field Club	R. S. Bagnall, F.L.S.
1	Warwickshire Naturalists' and Archæologists' Field Club	W. Andrews, F.G.S.
1 2	Woolhope Naturalists' Field Club	Rev. J. O. Bevan, M.A.
2	Yorkshire Naturalists' Union	T. Sheppard, F.G.S.

ASSOCIATED SOCIETIES.

1 2	Balham and District Antiquarian and Natural History Society	Sir Edward Brabrook, C.B.
1 2	Bradford Natural History and Microscopical Society	W. West, F.L.S.
1	Dunfermline Naturalists' Society	Dr. Chalmers Mitchell, F.R.S.
1 2	Grimsby and District Antiquarian and Naturalists' Society	Dr. O. T. Olsen, F.L.S.
1	Hastings and St. Leonards Natural History Society	George Willson.
2	Leeds Naturalists' Club and Scientific Association	Prof. J. H. Priestley, B.Sc
1 2	Lewisham Antiquarian Society	Sir Edward Brabrook, C.B
1 2	School Nature Study Union	Mrs. White, D.Sc.
1	South London Entomological and Natural History Society	Robert Adkin, F.E.S.
2	Teign Naturalists' Field Club	John S. Amery.
1	Watford Camera Club	John Hopkinson, F.G.S.

The representative of the Catford and District Natural History Society, Mr. E. Dixon, F.G.S., was absent, through a serious accident.

THE CORRESPONDING SOCIETIES OF THE BRITISH ASSOCIATION FOR 1913–1914.

Affiliated Societies.

Full Title and Date of Foundation	Headquarters or Name and Address of Secretary	No. of Members	Entrance Fee	Annual Subscription	Title and Frequency of Issue of Publications
Andersonian Naturalists' Society, 1885	Royal Technical College, Glasgow. R. Barnett Johnstone and Harry G. Cumming	291	2s. 6d.	2s. 6d.	Annals, occasionally.
Ashmolean Natural History Society of Oxfordshire, 1828	Miss A. L. Stone, 2 St. Margaret's Road, and Rev. C. F. Thornewill, 15 St. Margaret's Rd., Oxford	300	None	5s.	Report, annually.
Belfast Natural History and Philosophical Society, 1821	Museum, College Square. J. M. Finnigan.	200	None	1l. 1s.	Report and Proceedings, annually.
Belfast Naturalists' Field Club, 1863	A. W. Stelfox, Scottish Temperance Buildings, Donegall Square South, Belfast	331	5s.	5s.	Report and Proceedings, annually.
Berwickshire Naturalists' Club, 1831	Rev. J. J. M. L. Aiken, B.D., Manse of Ayton, Berwickshire	300	10s.	7s. 6d.	History of the Berwickshire Naturalists' Club, annually.
Birmingham and Midland Institute Scientific Society, 1859	Alfred Cresswell, Birmingham and Midland Institute, Paradise Street, Birmingham	132	None	10s. 6d. and 5s.	Records of Meteorological Observations, annually.
Birmingham Natural History and Philosophical Society, 1858	Avebury House, Newhall Street, Birmingham. W. H. Foxall, F.R.G.S.	204	None	1l. 1s.	Proceedings, occasionally.
Bournemouth Natural Science Society, 1903	Theo. Michell, Trewirgie, 37 Christchurch Road, Bournemouth	445	None	10s.	Proceedings, annually.
Brighton and Hove Natural History and Philosophical Society, 1854	J. Colbatch Clark, 9 Marlborough Place, Brighton	[illegible]	None	10s.	Report, annually.
Bristol Naturalists' Society, 1862	Dr. O. V. Darbishire, The University, Bristol	149	5s.	10s and 5s.	Proceedings, annually.
British Mycological Society, 1896	Carleton Rea, 34 Foregate Street, Worcester	110	None	10s.	Transactions, annually.
Buchan Club, 1887	J. F. Tocher, B.Sc., 5 Chapel Street, Peterhead	180	5s.	5s.	Transactions, annually.
Burton-on-Trent Natural History and Archæological Society, 1876	A. Slator, D.Sc., 174 Ashley Road, Burton-on-Trent	220	None	6s.	Report, annually; Transactions, occasionally.
Canada, Royal Astronomical Society of, 1884	Canadian Institute Building, Toronto. J. R. Collins	560	None	2 dollars	Journal, bi-monthly.
Caradoc and Severn Valley Field Club, 1893	H. E. Forrest, 37 Castle Street, Shrewsbury	210	5s.	5s.	Transactions and Record of Bare Facts, annually.
Cardiff Naturalists' Society, 1867	Dr. Owen L. Rhys, 26 Windsor Place, Cardiff	500	None	12s. 6d.	Transactions, annually.
Chester Society of Natural Science, Literature, and Art, 1871	Grosvenor Museum, Chester. G. P. Miln	952	None	5s. and 2s. 6d.	Report, annually; Proceedings, occasionally.
Cornwall, Royal Geological Society of, 1814	The Museum, Public Buildings, Penzance. John B. Cornish	84	None	1l. 1s.	Transactions, annually.
Cornwall, Royal Institution of, 1818	Henry Jenner, F.S.A., County Museum, Truro	202	None	1l. 1s.	Journal, annually.
Cornwall, Royal Polytechnic Society, 1833	E. W. Newton, 4 Cross Street, Camborne, Cornwall.	400	None	10s. upwards	Report, annually.
Cotteswold Naturalists' Field Club, 1846	L. Richardson, 10 Oxford Parade, Cheltenham.	110	1l.	15s.	Proceedings, annually.
Croydon Natural History and Scientific Society, 1870	Public Hall, Croydon. F. M. Roberts.	137	None	10s., 5s., and 2s. 6d.	Proceedings and Transactions, annually.
Dorset Natural History and Antiquarian Field Club, 1875	Rev. Herbert Pentin, M.A., Milton Abbey Vicarage, Dorset	400	10s.	10s.	Proceedings, annually.
Dublin Naturalists' Field Club, 1885	C. M. Selbie, B.Sc., National Museum, and G. R. Humphreys, Lyndale, Melrose Avenue, Fairview, Dublin	94	5s.	5s.	'Irish Naturalist,' monthly; Report, annually.

Dumfriesshire and Galloway Natural History and Antiquarian Society, 1862	G. W. Shirley, Ewart Public Library, Dumfries	423	None	5*s.*	Transactions and Proceedings, annually.
Durham, University of, Philosophical Society, 1896	J. W. Bullerwell and E. M. Eden, Armstrong College, Newcastle-on Tyne	200	None	10*s.*	Proceedings, half yearly.
East Anglia, Prehistoric Society of, 1908	W. G. Clarke, 12 St. Philip's Road, Norwich	185	None	5*s.*	Proceedings, annually.
East Kent Scientific and Natural History Society, 1857	A. Lander, 17 High Street, Canterbury	76	None	10*s.* and 5*s.*	Transactions, annually.
Eastbourne Natural History, Photographic, and Literary Society, 1867	T. J. Richards, 24 Broomfield Street, Eastbourne	136	2*s.* 6*d.*	5*s.*	Transactions and Journal, quarterly.
Edinburgh Field Naturalists' and Microscopical Society, 1869	Allan A. Pinkerton, 19 Shandwick Place, Edinburgh	225	None	5*s.*	Transactions, annually.
Edinburgh Geological Society, 1834	India Buildings, Edinburgh. W. T. Gordon	250	10*s.* 6*d.*	12*s.* 6*d.*	Transactions, annually.
Elgin and Morayshire Literary and Scientific Association, 1836	H. B. Mackintosh, Redhythe, Elgin	149	None	5*s.*	Transactions, occasionally.
Essex Field Club, 1880	Essex Museum of Natural History, Romford Road, Stratford. W. Cole and B. G. Cole	300	None	15*s.*	'Essex Naturalist,' quarterly; 'Year-book,' annually; 'Special Memoirs,' &c., occasionally.
Glasgow, Geological Society of, 1858	Peter Macnair, F.R.S.E., 207 Bath Street, Glasgow	250	None	10*s.*	Transactions and Proceedings, annually.
Glasgow, Natural History Society of, 1851	Alex. Ross, 409 Great Western Road, Glasgow	263	None	7*s.* 6*d.*	'Glasgow Naturalist,' quarterly.
Glasgow, Royal Philosophical Society of, 1802	Prof. Peter Bennett, 207 Bath Street, Glasgow	1,000	1*l.* 1*s.*	1*l.* 1*s.*	Proceedings, annually.
Hampshire Field Club and Archæological Society, 1885	W. Dale, F.S.A., F.G.S., The Lawn, Archer's Road, Southampton	250	5*s.*	10*s.* 6*d.*	Proceedings, annually.
Hampstead Scientific Society, 1899	C. O. Bartrum, B.Sc., and R. W. Wylie, M.A., 32 Willoughby Road, Hampstead, N.W.	344	None	Minimum 5*s.*	Report and Proceedings, annually.
Hertfordshire Natural History Society and Field Club, 1875	Charles Oldham, Kelvin, Berkhamsted, and E. J. Salisbury, Limbrick Hall, Harpenden	160	None	10*s.*	Transactions, annually.
Holmesdale Natural History Club, 1857	Miss M. C. Crosfield, Undercroft, Reigate	74	None	10*s.* and 5*s.*	Proceedings, occasionally.
Hull Geological Society, 1887	J. W. Stather, F.G.S., Newland Park, Hull	70	None	5*s.*	Transactions, occasionally.
Hull Scientific and Field Naturalists' Club, 1886	T. Stainforth, B.A., The Museum, Hull	131	None	5*s.*	Transactions, annually.
Institution of Mining Engineers, 1889	Percy Strzelecki, 39 Victoria Street, London, S.W.	3,400	None	None	Transactions, monthly.
Ireland, Statistical and Social Inquiry Society of, 1847	W. Lawson, Dr. N. M. Falkiner, and Herbert Wood, 93 Stephen's Green, Dublin	90	None	1*l.*	Journal, annually.
Leeds Geological Association, 1873	E. Hawkesworth, Cross Gates, Leeds	125	None	5*s.*	Transactions, occasionally.
Leicester Literary and Philosophical Society, 1835	Corporation Museum. C. H. Spencer, 50 Knighton Drive, Leicester	289 Membs. & Associates	None	Members 1*l.* 1*s.*; Associates 10*s.* 6*d.*	Transactions, annually.
Lincolnshire Naturalists' Union, 1893	Arthur Smith, F.L.S., City and County Museum, Lincoln	112	None	5*s.*	Transactions, annually.
Liverpool Biological Society, 1886	J. A. Clubb, D.Sc., Free Public Museum, Liverpool	80	10*s.* 6*d.*	1*l.* 1*s.*	Proceedings and Transactions, annually.
Liverpool Botanical Society, 1906	A. A. Dallman, F.C.S., 63 Sea View Road, Wallasey, Cheshire, and Miss M. B. Barr, 25 Deane Road, Fairfield, Liverpool	130	None	5*s.*	Proceedings, annually; Transactions, occasionally.
Liverpool Engineering Society, 1875	T. R. Wilton, M.A., 1 Crosshall Street, Liverpool	603	None	1*l.* 1*s.*, 10*s.* 6*d.*, and 5*s.*	Transactions and Report, annually.
Liverpool Geographical Society, 1891	A. Ellis Cookson, 14 Hargreave's Buildings, Liverpool	500	None	Members 1*l.* 1*s.*; Associates 10*s.* 6*d.*	Transactions and Report, annually.
Liverpool Geological Society, 1858	Royal Institution. W. A. Whitehead, B.Sc.	77	None	10*s.* 6*d.*	Proceedings, annually.

Affiliated Societies—continued

Full Title and Date of Foundation	Headquarters or Name and Address of Secretary	No. of Members	Entrance Fee	Annual Subscription	Title and Frequency of Issue of Publications
London: Quekett Microscopical Club, 1865	Jas. Burton, 8 Somali Road, West Hampstead, N.W.	420	None	10*s.*	Journal, half-yearly.
London: Selborne Society, 1885	42 Bloomsbury Square, W.C. W. M. Webb, F.L.S.	3,111	None	5*s.*	'Selborne Magazine,' monthly.
Man, Isle of, Natural History and Antiquarian Society, 1879	P. M. C. Kermode, Glen Aldyn, Ramsey, Isle of Man	238	2*s.* 6*d.*	7*s.* 6*d.* and 5*s.*	Proceedings and Transactions, annually.
Manchester Geographical Society, 1884	J. Howard Reed and E. Steinthal, 16 St. Mary's Parsonage, Manchester	690	None	Members 1*l.* 1*s.*; Associates 10*s.* 6*d.*	Journal, quarterly.
Manchester Geological and Mining Society, 1838	5 John Dalton Street, Manchester. Sydney A. Smith	400	None	2*l.* 2*s.*, 1*l.* 5*s.*, and 1*l.*	Transactions of Inst. of Mining Engineers, monthly.
Manchester Microscopical Society, 1880	Frederick Dishley, 14 Westwood Street, Moss Side, Manchester	180	5*s.*	6*s.*	Transactions and Report, annually.
Manchester Statistical Society, 1833	Herbert Heape and F. Vernon Hansford, 3 York Street, Manchester	171	10*s.* 6*d.*	10*s.* 6*d.*	Transactions, annually.
Marlborough College Natural History Society, 1864	E. Meyrick, F.R.S., Marlborough College	370	1*s.* 6*d.*	3*s.* and 5*s.*	Report, annually.
Midland Counties Institution of Engineers, 1871	G. Alfred Lewis, M.A., Midland Road, Derby	385	1*l.* 1*s.*	2*l.* 2*s.* and 1*l.*	Transactions of Institution of Mining Engineers, monthly.
Norfolk and Norwich Naturalists' Society, 1869	S. H. Long, M.D., 37 St. Giles Street, Norwich	290	None	6*s.*	Transactions, annually.
North of England Institute of Mining and Mechanical Engineers, 1852	Neville Hall, Newcastle-upon-Tyne. Lawrence Austin	1,298	None	25*s.* and 42*s.*	Transactions of Inst. of Mining Engineers, monthly.
North Staffordshire Field Club, 1865	W. Wells Bladen, Stone, Staffs	666	5*s.*	5*s.*	Report and Transactions, annually.
Northamptonshire Natural History Society and Field Club, 1876	H. N. Dixon, M.A., 17 St. Matthew's Parade, Northampton	210	None	10*s.*	Journal, quarterly.
Northumberland, Durham, and Newcastle-upon-Tyne, Natural History Society of, 1829	Hancock Museum, Newcastle-on-Tyne. C. E. Robson and J. A. Richardson	450	None	21*s.*	Transactions, annually.
Nottingham Naturalists' Society, 1852	Prof. J. W. Carr, M.A., University College, Nottingham	150	2*s.* 6*d.*	5*s.*	Report and Transactions, annually.
Paisley Philosophical Institution, 1808	J. Gardner, 3 County Place, Paisley	531	5*s.*	7*s.* 6*d.*	Report and Meteorological Observations, annually.
Perthshire Society of Natural Science, 1867	Tay Street, Perth. S. T. Ellison	330	None	5*s.* 6*d.*	Transactions and Proceedings, annually.
Rochdale Literary and Scientific Society, 1878	J. Reginald Ashworth, D.Sc., 105 Freehold Street, Rochdale	243	None	6*s.*	Transactions, biennially.
Rochester Naturalists' Club, 1878	John Hepworth, Linden House, Rochester	150	None	5*s.*	'Rochester Naturalist,' quarterly.
Sheffield Naturalists' Club, 1870	C. Bradshaw, Public Museum, and A. Brittain, 47 Bank Street, Sheffield	106	None	5*s.*	Report, bi-annually; Proceedings, occasionally.

Somersetshire Archæological and Natural History Society, 1849	The Castle, Taunton. Rev. F. W. Weaver, Rev. E. H. Bates Harbin, and C. Tite	877	10*s*. 6*d*.	10*s*. 6*d*.	Proceedings, annually.
South Africa, Royal Society of, 1906	G. M. Clark, South African Museum, Cape Town	207	None	2*l*.	Transactions, occasionally.
South-Eastern Union of Scientific Societies, 1896	William Martin, LL.D., F.S.A., 2 Garden Court, Temple, E.C.	64 Societies	None	Minimum 5*s*.	'South-Eastern Naturalist,' annually.
Southport Literary and Philosophical Society	A. H. Garstang, 82 Forest Road, Southport	180	None	7*s*. 6*d*.	Proceedings, occasionally.
South Staffordshire and Warwickshire Institute of Mining Engineers, 1867	G. D. Smith, 3 Newhall Street, Birmingham	150	1*l*. 1*s*. and 10*s*. 6*d*.	42*s*. and 21*s*.	Transactions of Institution of Mining Engineers, monthly.
Torquay Natural History Society, 1844	Harford J. Lowe, F.G.S., The Museum, Torquay	180	10*s*. 6*d*.	1*l*. 1*s*.	Journal, annually.
Tyneside Geographical Society, 1887	Geographical Institute, St. Mary's Place, Newcastle-on-Tyne. Herbert Shaw, B.A.	800	None	21*s*. and 10*s*.	Journal, quarterly.
Vale of Derwent Naturalists' Field Club, 1887	J. E. Patterson, Mossgiel, Rowlands Gill, R.S.O.	160	None	2*s*. 6*d*.	Transactions, occasionally.
Warwickshire Naturalists' and Archæologists' Field Club, 1854	Museum, Warwick. C. West, Cross Cheaping, Coventry	70	2*s*. 6*d*.	5*s*.	Proceedings, annually.
Woolhope Naturalists' Field Club, 1851	Woolhope Club Room, Free Library, Hereford. T. Hutchinson	225	10*s*.	10*s*.	Transactions, occasionally.
Worcestershire Naturalists' Club, 1847	Education Offices, Worcester. F. T. Spackman, F.G.S.	190	10*s*.	5*s*.	Transactions, annually.
Yorkshire Geological Society, 1837	Cosmo Johns, Burngrove, Pitsmoor Road, Sheffield	200	None	13*s*.	Proceedings, annually.
Yorkshire Naturalists' Union, 1861	The Museum, Hull. T. Sheppard, F.G.S.	431 and 3,301 Associates	None	10*s*. 6*d*.	Transactions, annually; 'The Naturalist,' monthly.
Yorkshire Philosophical Society, 1822	Museum, York. C. E. Elmhirst	450	None	2*l*. and 1*l*.	Report, annually.

Associated Societies.

Balham and District Antiquarian and Natural History Society, 1897	A. L. Barron, Clophill, Wallington, Surrey	75	None	5*s*.	Report, annually; Papers, occasionally.
Barrow Naturalists' Field Club and Literary and Scientific Association, 1876	W. L. Page, 5 Cavendish Street, Barrow	270	None	5*s*. and 2*s*. 6*d*.	Report and Proceedings, annually.
Battersea Field Club, 1894	Public Library, Lavender Hill, Battersea, S.W. Miss L. B. Morris	65	2*s*. 6*d*	3*s*. 6*d*.	—
Bradford Natural History and Microscopical Society, 1875	Fred. Jowett, 2 Vincent Street, Bradford	8	1*s*.	4*s*.	Report, annually.
Bradford Scientific Association, 1875	W. Newbould, 34 Burnett Avenue, Bradford	170	None	5*s*. and 2*s*. 6*d*.	—
Catford and District Natural History Society, 1897	W. H. Griffin, 94 Ravensbourne Road, Catford, S.E.	87	None	5*s*.	—
Dunfermline Naturalists' Society, 1902	Robert Somerville, B.Sc., 38 Cameron Street, Dunfermline	150	None	5*s*.	—
Ealing Scientific and Microscopical Society, 1877	F. McNeil Rushforth, Coley Lodge, 21 Florence Road, Ealing, W.	146	None	10*s*. and 2*s*. 6*d*.	Report and Transactions, annually.
Grimsby and District Antiquarian and Naturalists' Society, 1896	The Museum, Grimsby. F. W. Sowerby	85	None	4*s*.	—

Associated Societies—continued.

Full Title and Date of Foundation	Headquarters or Name and Address of Secretary	No. of Members	Entrance Fee	Annual Subscription	Title and Frequency of Issue of Publications
Halifax Scientific Society, 1874	J. H. Lumb, 32 Undercliffe Terrace, Halifax	144	None	2*s.* 6*d.*	—
Hastings and St. Leonards Natural History Society, 1893	W. de Muller, B.A., 14 St. Matthew's Gardens, St Leonards-on-Sea	439	1*s.*	3*s.* 6*d.*	'Hastings and East Sussex Naturalist,' occasionally.
Hawick Archæological Society, 1856	J. J. Vernon, 81 High Street, Hawick	300	None	2*s.* 6*d.*	Transactions, annually.
Inverness Scientific Society and Field Club, 1875	Thomas Wallace, Ellerslie, Inverness	180	None	5*s.*	Transactions, occasionally.
Ipswich and District Field Club, 1903	F. J. Fletcher, The Drift, Britannia Road, Ipswich	150	None	2*s.* 6*d.*	Journal, annually.
Lancashire and Cheshire Entomological Society, 1877	Royal Institution, Liverpool. William Mansbridge	99	None	5*s.*	Report and Proceedings, annually.
Leeds Naturalists' Club and Scientific Association, 1868	Edward J. T. Ingle, 18 Strattan Street, Leeds	110	None	5*s.*	Proceedings, occasionally.
Lewisham Antiquarian Society, 1885	J. W. Brookes, Pembroke Lodge, Slaithwaite Road, Lewisham, S.E.	77	None	5*s.*	Transactions, occasionally.
Liverpool Microscopical Society, 1868	Royal Institution, Liverpool. R Croston	56	None	10*s.* 6*d.*	Report, annually.
Llandudno and District Field Club, 1906	L. S. Underwood, Brinkburn, Llandudno	175	None	5*s.*	Proceedings, annually.
London: City of London Entomological and Natural History Society, 1858	The London Institution, Finsbury Circus, E.C. V. E. Shaw.	78	2*s.* 6*d.*	7*s.* 6*d.*	Transactions, annually.
London: North London Natural History Society, 1892	T. R. Brooke, F.R.M.S., 12 Warren Road, Chingford	222	2*s.* 6*d.*	5*s.* and 2*s.* 6*d.*	Report, annually.
London: South London Entomological and Natural History Society, 1872	Hibernia Chambers, London Bridge, S.E. Stanley Edwards, F.L.S., and H. J. Turner, F.E.S.	172	2*s.* 6*d.*	10*s.*	Proceedings, annually.
Maidstone and Mid-Kent Natural History Society, 1868	Maidstone Museum. A. Barton and J. W. Bridge	85	None	10*s.*	Report, occasionally.
Newcastle-upon-Tyne, Literary and Philosophical Society of, 1793	Newcastle-upon-Tyne. Alfred Holmes and Frederick Emley	3,006	None	1*l.* 1*s.*	—
Preston Scientific Society, 1893	Lecture Hall, 119A Fishergate, Preston. F. Chadderton	400	None	5*s.*	Papers, occasionally.
Scarborough Philosophical and Archæological Society, 1828	E. Arnold Wallis, Springfield, and A. J. Burnley, 43 Moorland Road, Scarborough	110	None	1*l.*, 10*s.*, and 5*s.*	Report, annually.
School Nature Study Union, 1903	H. E. Turner, 1 Grosvenor Park, Camberwell, S.E.	1,650	None	2*s.* 6*d.*	'School Nature Study,' five times a year.
Southport Society of Natural Science, 1890	P. H. Christian, 9 Russell Road, Southport	240	None	5*s.*	Report, annually.
Teign Naturalists' Field Club, 1858	John S. Amery, Druid, Ashburton, Devon	120	None	2*s.* 6*d.*	Report, annually.
Tunbridge Wells Literary and Natural History Society, 1884	Dr. D. Davies, 8 Lonsdale Gardens, Tunbridge Wells	156	None	10*s.* 6*d.* and 5*s.*	Report, annually.
Watford Camera Club and Photographic Society, 1902	P. H. Haines, 100 High Street, Watford	80	None	10*s.* 6*d.*	—

Catalogue of the more important Papers, especially those referring to Local Scientific Investigations, published by the Corresponding Societies during the year ending May 31, 1913.

*** This Catalogue contains only the titles of papers published in the volumes or parts of the publications of the Corresponding Societies sent to the Secretary of the Committee in accordance with Rule 2.

Section A.—MATHEMATICAL AND PHYSICAL SCIENCE.

BIGGER, CHARLES A. The Geodetic Survey of Canada. 'Journal Royal Astr. Soc. of Canada,' VI. 324–342. 1912.

CANNON, J. B. The Orbit of β Coronæ Borealis. 'Journal Royal Astr. Soc. of Canada,' VI. 342–349. 1912.

—— The Orbit of ζ Persei from the H and K Lines. 'Journal Royal Astr. Soc. of Canada,' VI. 188–196. 1912.

CARADOC AND SEVERN VALLEY FIELD CLUB. Meteorological Notes. 'Record of Bare Facts,' No. 22, 25–42. 1913.

CHANT, C. A. In the Background of the Stars. 'Journal Royal Astr. Soc. of Canada, VI. 240–245. 1912.

CONRADY, A. E. Resolution with Dark-ground Illumination. 'Journal Quekett Mic. Club,' XI. 475–480. 1912.

CRESSWELL, ALFRED. Records of Meteorological Observations taken at the Observatory, Edgbaston, 1912. 'Birm. and Mid. Inst. Sci. Soc.' 26 pp. 1913.

DUMFRIESSHIRE AND GALLOWAY NATURAL HISTORY AND ANTIQUARIAN SOCIETY. Abstract of Meteorological Observations taken at Crichton Royal Institution, Dumfries, 1911. 'Trans. Dumfriesshire and Galloway N. H. A. Soc.' XXIV. 212–213. 1912.

ESPIN, T. E. The Dark Structures in the Milky Way. 'Journal Royal Astr. Soc. of Canada,' VI. 225–230. 1912.

—— The Milky Way, and the Distribution of Stars with Peculiar Spectra. 'Journal Royal Astr. Soc. of Canada,' VII. 79–87. 1913.

FOX, W. LLOYD, and EDWARD KITTO. Meteorological and Magnetical Tables and Reports for the year 1911, Tables of Sea Temperature, &c. 'Report Royal Cornwall Poly. Soc.' II. (N.S.) 1–28 (App.). 1912.

GARRETT, Dr. F. C., and R. C. BURTON (N. Eng. Inst. Eng.). The Use of *X*-rays in the Examination of Coal. 'Trans. Inst. Min. Eng.' XLIII. 295–297. 1912.

GIBBS, THOMAS. Rainfall Records at Wirksworth, Derbyshire. 'The Naturalist for 1913,' 105–108. 1913.

GRAY, ROBERT C. On the Magnetism of Aluminium Bronze. 'Proc. Glasgow Royal Phil. Soc.' XLIII. 104–106. 1912.

HALDANE, Dr. J. S., and Dr. T. LISTER LLEWELLYN (S. Staffs. and Warw. Inst. Eng.). The Effects of Deficiency of Oxygen on the Light of a Safety-lamp. 'Trans. Inst. Min. Eng.' XLIV. 267–272. 1912.

HARDY, V. C. Meteorological Observations at Oundle School, 1911. 'Journal Northants. N. H. Soc.' XVI. 264. 1912.

HARPER, W. E. A Long-Period Spectroscopic Binary. 'Journal Royal Astr. Soc. of Canada,' VI. 179–187. 1912.

—— Further Observations of θ Aquilæ. 'Journal Royal Astr. Soc. of Canada,' VI. 265–271. 1912.

HAWKE, E. L. Meteorological Report for 1912. 'Report Hampstead Sci. Soc., 1912,' 27–28. 1912.

HOPKINSON, JOHN. The Weather of the Year 1910 in Hertfordshire. 'Trans. Herts N. H. S. F. C.' XIV. 255–270. 1912.

HOUGH, S. S. Presidential Address: Some Recent Improvements in Transit Observing. 'Trans. Royal Soc. of S. Africa,' II. 419–427. 1912.

HOWARD, A. G. The Blizzard of June 9–12, 1902. 'Trans. Royal Soc. of S. Africa,' III. 129–134. 1913.

MACE, Lieut. F. W. Harbour Surveying. 'Trans. Liverpool Eng. Soc.' XXXIII. 54–75. 1912.

Markham, C. A., and R. H. Primavesi. Meteorological Report. 'Journal Northants N. H. Soc.' xvi. 217–220, 260–263, 300–306. 1912, 1913.

Meyrick, E. Summary and Tables of Meteorological Observations. 'Report Marlb. Coll. N. H. Soc.' No. 60, 97–118. 1912.

Moir, Dr. James. The Spectrum of the Ruby—Part III. 'Trans. Royal Soc. of S. Africa,' ii. 339–340. 1912.

Moore, A. W. The Climate of the Isle of Man. 'Proc. Isle of Man N. H. A. Soc.' (n.s.) i. 447–454. 1913.

Muir, Dr. Thomas. The Resultant of a Set of Homogeneous Lineo-linear Equations. 'Trans. Royal Soc. of S. Africa,' ii. 373–380. 1912.

—— Note on Double Alternants. 'Trans. Royal Soc. of S. Africa,' iii. 177–185. 1913.

Nelson, Robert (N. Staffs Inst. Eng.). Electricity: A Short Paper addressed to Colliery Managers. 'Trans. Inst. Min. Eng.' xlv. 156–164. 1913.

Patterson, T. L. Study of a Falling Chimney. 'Proc. Glasgow Royal Phil. Soc.' xliii. 217–231. 1912.

Plaskett, J. S. The Spectroscopic Binary θ^2 Tauri. 'Journal Royal Astr. Soc. of Canada,' vi. 231–239. 1912.

Pope, Alfred. Some Dew-ponds in Dorset. 'Proc. Dorset N.H.A.F.C.' xxxiii. 22–33. 1912.

Preston, Arthur W. Meteorological Notes, 1911. 'Trans. Norfolk and Norwich Nat. Soc,' ix. 341–348. 1912.

Rambaut, A. A. Characteristics of the Weather at Oxford in 1912. 'Report Ashmolean Nat. Hist. Soc. 1912,' 41. 1913.

—— Summary of the Weather during 1912, from Observations at the Radcliffe Observatory, Oxford. 'Report Ashmolean Nat. Hist. Soc. 1912,' 42. 1913.

Reid, Duncan J. Critical Illumination in Visual Work with the Microscope. 'Journal Quekett Mic. Club,' xi. 487–496. 1912.

Reid, F. B. Precise Levelling in Canada. 'Journal Royal Astr. Soc. of Canada,' vi. 151–178. 1912.

Rheinberg, Julius. On Resolutions obtained with Dark-ground Illumination and their Relation to the Abbe Theory. 'Journal Quekett Mic. Club,' xi. 501–506. 1912.

Rodger, Alex. M. Abstract of Meteorological Observations, Perth, 1911, and Remarks on the Weather. 'Proc. Perthshire Soc. Nat. Sci.' v. clxxxii.–clxxxv. 1912.

Ross, Dr. Alexander D. Some Physical Properties of Alloys of Iron and Copper. 'Proc. Glasgow Royal Phil. Soc.' xliii. 62–66. 1912.

—— and John J. Ross. On a further Relation between Seismic Frequency and the Motion of the Earth's Pole. 'Proc. Glasgow Royal Phil. Soc.' xliii. 97–103. 1912.

Ross, Dr. Maxwell. Meteorological Observations taken at Dumfries, 1909 and 1910. 'Trans. Dumfriesshire and Galloway N. H. A. Soc.' xxiv. 301–303. 1912.

Rudge, W. A. Douglas. Action of Radium Salts on Glass. 'Trans. Royal Soc. of South Africa,' ii. 357–364. 1912.

—— On the Variation in the Value of the Atmospheric Electrical Potential with the Altitude. 'Trans. Royal Soc. of S. Africa,' ii. 395–404. 1912.

Rutherford, J. Weather and Natural History Notes, 1911. 'Trans. Dumfriesshire and Galloway N. H. A. Soc.' xxiv. 214–223. 1912.

Schlesinger, Frank. The Responsibilities of an Observatory Staff. 'Journal Royal Astr. Soc. of Canada,' vi. 283–289. 1912.

Sheppard, T. Early Microscopes. 'The Naturalist for 1912,' 229–234. 1912.

Simpson, T. V., and G. W. Bell. A Photographic Method of rapidly Copying out Pay-notes, in use at Throckley Collieries. 'Trans. Inst. Min. Eng.' xliv. 220–227. 1912.

Steadworthy, A. Photographing Lightning. 'Journal Royal Astr. Soc. of Canada,' vi. 322–323. 1912.

Stewart, Louis B. President's Address: The Structure of the Universe. 'Journal Royal Astr. Soc. of Canada,' vii. 1–18. 1913.

Stewart, Thomas. The Rainfall on Table Mountain. 'Trans. Royal Soc. of S. Africa,' iii. 41–46. 1913.

Stilwell, H. Remarks on Rainfall of 1911. 'Proc. Dorset N. H. A. F. C.' xxxiii. 147–160. 1912.

Stokes, W. B. On Resolutions obtained with Dark-ground Illumination and their Relation to the Spectrum Theory. 'Journal Quekett Mic. Club,' xi. 497–500. 1912.

Sutton, Dr. J. R. On some Meteorological Conditions controlling Nocturnal Radiation. 'Trans. Royal Soc. of S. Africa,' ii. 381–393. 1912.

SUTTON, Dr. J. R., and ELIZABETH M. SUTTON. Some Causes and Effects of Variations in the Range of Temperature. 'Trans. Royal Soc. of S. Africa,' II. 341–356. 1912.
TURNBULL, F. B. Iceland Spar and the Polariscope. 'Trans. Edinburgh F. N. Mic. Soc.' VI. 439–447. 1912.
WALFORD, Dr. E. Meteorological Observations in the Society's District, 1910. 'Trans. Cardiff Nat. Soc.' XLIV. 1–18. 1912.
—— The Cardiff Seismograph. 'Trans. Cardiff Nat. Soc., XLIV. 19–20. 1912.
WATT, ANDREW. Rainfall Records of the Southern Counties for the year 1911. 'Trans. Dumfriesshire and Galloway N. H. A. Soc.' XXIV. 210–212. 1912.
WILSON, C. J. (Min. Inst. Scotland). An Investigation into the Effect of Atmospheric Pressure on the Height of the Gas-cap. 'Trans. Inst. Min. Eng.' XLV. 67–78. 1913.
YOUNG, A. Photographing Halley's Comet with Home-made Apparatus. 'Journal Royal Astr. Soc. of Canada,' VI. 281–282. 1912.
YOUNG, ANDREW. Tidal Phenomena at Inland Boreholes near Cradock. 'Trans. Royal Soc. of S. Africa,' III. 61–106. 1913.

Section B.—CHEMISTRY.

ARMSTRONG, Prof. H. E. Some Consequences of Graham's Work: The Nature of the Elements: The Diffusion of Liquids. 'Proc. Glasgow Royal Phil. Soc.' XLIII. 67–96. 1912.
BLACKETT, W. C. (N. England Inst. Eng.). An Address to Practical Men, being some further notes on the Combustion of Oxygen and Coal-dust in Mines. 'Trans. Inst. Min. Eng.' XLV. 295–308. 1913.
DESCH, Dr. CECIL H. The Crystallisation of Metals. 'Proc. Glasgow Royal Phil. Soc.' XLIII. 107–120. 1912.
ELLIOTT, T. LENTON. Chemical Constituents of 'Moorlog.' 'The Naturalist for 1913,' 268–269. 1912.
FERGUSON, Prof. JOHN. Some Early Treatises on Technological Chemistry. Supplement III. 'Proc. Glasgow Royal Phil. Soc.' XLIII. 232–258. 1912.
FULLER, CHARLES J. P. (Manchester Geol. Min. Soc.). The Microscopic Structure of Metals. 'Trans. Inst. Min. Eng.' XLV. 266–267. 1913.
MOIR, Dr. JAMES. Valency and Chemical Affinity. 'Trans. Royal Soc. of S. Africa.' III. 39–40. 1913.
SUTTON, W. LINCOLNE. Presidential Address: Enzymes, with Special Reference to Cyanogenesis. 'Trans. Norfolk and Norwich Nat. Soc.' IX. 285–299. 1912.
THOMPSON, BEEBY. Peculiarities of Waters and Wells. 'Journal Northants N. H. Soc.' XVI. 247–257. 1912.

Section C.—GEOLOGY.

ARBER, Dr. E. A. NEWELL. The Fossil Plants of the Forest of Dean Coalfield. 'Proc. Cotteswold Nat. Field Club,' XVII. 321–332. 1912.
BATHER, F. A. Notes on Hydreionocrinus. 'Trans. Edinburgh Geol. Soc.' X. 61–76, 1912.
—— Tapering Ends of Crinoid Stems from Roscobie. 'Trans. Edinburgh Geol. Soc.' X. 77–79. 1912.
BELL, ALFRED. On the Zonal Stratification of the Eastern British Pliocenes. 'Essex Naturalist,' XVI. 289–305. 1912.
BURTON, J. J. The Cleveland Ironstone. 'The Naturalist for 1913,' 161–168, 185–194. 1913.
CHATWIN, CHARLES P. The Cretaceous Lamellibranchia of Yorkshire. 'The Naturalist for 1913,' 201–204. 1913.
COATES, HENRY. Note on the Occurrence of a Beam of Timber under Carse Clay at Barnhill. 'Proc. Perthshire Soc. Nat. Sci.' V. cxliv.–cxlv. 1912.
COCKRILL, H. W. Instruments in a Land-stratum at Lyng. 'Proc. Prehistoric Soc. of East Anglia,' I. 169–170. 1913.
CRAIG, R. M. Additions to the Volcanic Geology of East Fife. 'Trans. Edinburgh Geol. Soc.' X. 83–89. 1912.
—— and DAVID BALSILLIE. The Carboniferous Rocks and Fossils in the neighbourhood of Pitscottie, Fifeshire. 'Trans. Edinburgh Geol. Soc.' X. 10–24, 1912.
DALTON, ARCHIBALD C. Quartzite Boulders in the Scunthorpe District. 'The Naturalist for 1912,' 235. 1912.

DAWKINS, Prof. W. BOYD (Manchester Geol. Min. Soc.). The South-Eastern Coal-field, the Associated Rocks, and the Buried Plateau. 'Trans. Inst. Min. Eng.' XLIV. 350–375. 1913.

DAY, T. CUTHBERT. Some Observations on the Long Row and the Dasses, Arthur's Seat. 'Trans. Edinburgh Geol. Soc.' X. 40–48. 1912.

DRON, R. W. Notes on Bores in Manor-Powis Coalfield, Stirling. 'Trans. Edinburgh Geol. Soc.' X. 25–29. 1912.

GIBSON, Dr. WALCOT. (S. Staffs. and Warw. Inst. Min. Eng.). A Boring for Coal at Claverley, near Bridgnorth, and its bearing on the extension westwards of the South Staffordshire Coalfield. 'Trans. Inst. Min. Eng.' XLV. 30–38. 1913.

GILLIGAN, ALBERT. The Millstone Grit of Yorkshire: Some new Evidence as to its Source of Origin. 'The Naturalist for 1912,' 362–363. 1912.

GRAY, JOSEPH W. The Lower Severn Plain during the Glacial Epoch. 'Proc. Cotteswold Nat. Field Club,' XVII. 365–380. 1912.

GREGORY, Dr. J. W. The Polmont Kame, and on the Classification of Scottish Kames. 'Trans. Glasgow Geol. Soc.' XIV. 199–218. 1913.

GWINNELL, WINTOUR F. The Geology of the Folkestone Warren. 'South-Eastern Naturalist for 1912,' 59–65. 1912.

HALLISSY, T. On the Superficial Deposits of the County of Wexford. 'Irish Naturalist,' XXI. 175–179. 1912.

HAMPSTEAD SCIENTIFIC SOCIETY. Hampstead Heath: its Geology and Natura History. 328 pp. 1913.

HARGREAVES, J. A. Fossil Footprints near Scarborough. 'The Naturalist for 1913,' 92–95. 1913.

HARKER, ALFRED. Lamprophyre Dykes in Long Sleddale, Westmorland. 'The Naturalist for 1912,' 266–267. 1912.

HAWARD, F. N. The Chipping of Flints by Natural Agencies. 'Proc. Prehistoric Soc. of East Anglia,' I. 185–193. 1912.

HAWKESWORTH, EDWIN. A Pre-Glacial Lake-bed near Northallerton. 'The Naturalist for 1912,' 204–205. 1912.

HERON-ALLEN, EDWARD, and ARTHUR EARLAND. The Foraminifera in their rôle as World-builders: A Review of the Foraminiferous Limestones and other Rocks of the Eastern and Western Hemispheres. 'Journal Quekett Mic. Club,' XII. 1–16. 1913.

HEWITT, W. Presidential Address: The Coast in its Geological Relations. 'Proc. Liverpool Geol. Soc.' XI. 153–182. 1912.

HINCH, J. DE W. The Shelly Drift of Glenulra and Belderrig, Co. Mayo. 'Irish Naturalist,' XXII. 1–6. 1913.

HOLLAND, Prof. Sir THOS. H. The Origin of Desert Salt Deposits. 'Proc. Liverpool Geol. Soc.' XI. 227–250. 1912.

JONES, T. A. Petrographical Studies of Local Erratics. 'Proc. Liverpool Geol. Soc.' XI. 183–200. 1912.

KIDNER, HENRY. Notes on the Geology of Western Hertfordshire. 'Trans. Herts N. H. S. F. C.' XIV. 298. 1912.

LOMAX, JAMES (Manchester Geol. Min. Inst.). Natural History of Coal and Coal-dust. 'Trans. Inst. Min. Eng.' XLIV. 288–301. 1912.

MACGREGOR, M. The Garriongill Section at Overtown, near Wishaw. 'Trans. Glasgow Geol. Soc.' XIV. 279–290. 1913.

MACKIE, Dr. WILLIAM. Further Evidence of Contemporaneous Volcanic Action during the Period of the Dalradian Schists. 'Trans. Edinburgh Geol. Soc.' X. 80–81. 1912.

—— On some Characters of a Dyke Rock associated with the Foliated Gabbros of Glen Ernan, Aberdeenshire. 'Trans. Edinburgh Geol. Soc.' X. 82. 1912.

MACNAIR, PETER, and HARRY R. J. CONACHER. On the Distribution of *Posidonomya corrugata* Ether. Jun. in the Carboniferous Limestone of the Glasgow District. 'Trans. Glasgow Geol. Soc.' XIV. 309–322. 1913.

NELSON, JAMES. Notes on the Geological Survey Memoir—The Geology of the Glasgow District. 'Trans. Glasgow Geol. Soc.' XIV. 323–343. 1913.

ORD, Dr. WILLIAM T. The Geology of Cheddar Cliffs. 'Proc. Bournemouth Nat. Sci. Soc.' IV. 89–94. 1913.

PICTON, HAROLD. Observations on the Bone Bed at Clacton. 'Proc. Prehistoric Soc. of East Anglia,' I. 158–159. 1913.

PRESTON, HENRY. History in Rocks and Stones, with special reference to Cuckmere Haven. 'Trans. Eastbourne N. H., Sci., and Lit. Soc.' (N.S.) 4, 25–35. 1912.

PRINGLE, JOHN. On the Origin of Bright Laminæ in Coal, and a Suggestion arising out of their Distribution. 'Trans. Edinburgh Geol. Soc.' x. 30–37. 1912.

REOCH, JAMES W. Notes on the Occurrence of Chalcedony, Agate, and Crystalline Quartz in the Lavas of the Campsie Hills. 'Trans. Glasgow Geol. Soc.' XIV. 303–308. 1913.

RICHARDSON, L. Memoir explanatory of a Map of a part of Cheltenham and Neighbourhood, showing the Distribution of the Sand, Gravel, and Clay. 'Proc. Cotteswold Nat. Field Club,' XVII. 297–319. 1912.

—— The Water Supply of the City of Gloucester; with Historical Note and Appendix, by Roland Austin. 'Proc. Cotteswold Nat. Field Club,' XVII. 345–363. 1912.

—— A 'Swallow-hole' in the Inferior Oolite, near Cheltenham. 'Proc. Cotteswold Nat. Field Club,' XVIII. 65. 1913.

—— and CHARLES UPTON. Some Inferior Oolite Brachiopoda. 'Proc. Cotteswold Nat. Field Club,' XVIII. 47–58. 1913.

—— and E. TALBOT PARIS. On the Stratigraphical and Geographical Distribution of the Inferior Oolite Echinoids of the West of England: Supplement. 'Proc. Cotteswold Nat. Field Club,' XVIII. 73–82. 1913.

SAWYER, A. R. (N. Staffs. Inst. Eng.). The New Rand Goldfield. 'Trans. Inst. Min. Eng.' XLIV. 4–17. 1912.

SHEPPARD, GEORGE. Some recent Discoveries in the Chalk of the Flamboro' District. 'The Naturalist for 1912,' 337–338. 1912.

SHEPPARD, T. Bibliography. Papers and Records published with respect to the Geology and Palæontology of the North of England (Yorkshire excepted) during 1910. 'The Naturalist for 1912,' 188–190. 1912.

—— —— during 1911. 'The Naturalist for 1912,' 345–352, 371–372. 1912.

—— Coast Changes at Hornsea. 'The Naturalist for 1913,' 99. 1913.

SMELLIE, WILLIAM R. The Sandstones of the Upper Red Barren Measures to the East of Glasgow. 'Trans. Glasgow Geol. Soc.' XIV. 258–278. 1913.

SPICER, Rev. C. E. Present Trias Conditions in Australia. 'Proc. Liverpool Geol. Soc.' XI. 201–209. 1912.

STEUART, D. R. The Occurrence of Petroleum at Broxburn. 'Trans. Edinburgh Geol. Soc.' x. 38–39. 1912.

STRACHAN, JAMES. Beekite or Cycloidal Chalcedony. 'Proc. Belfast Nat. F. C.' VI. 536–547. 1912.

SWANTON, E. W. The Mollusca of Somerset (*conclusion*). 'Proc. Somersetshire Arch. N. H. Soc.' LVIII. i–viii, 55–86. 1913.

SWINNERTON, Dr. H. H. The Palmistry of the Rocks. 'Report Nottingham Nat. Soc. 1911–12,' 65–68. 1912.

TAIT, D. On a large glacially transported Mass of Lower Cretaceous Rock at Leavad in the County of Caithness. 'Trans. Edinburgh Geol. Soc.' x. 1–9. 1912.

THOMPSON, PERCY G. Note on the Occurrence of Stony Beds underlying Harwich Harbour. 'Essex Naturalist,' XVI. 305–309. 1912.

TYRRELL, G. W. The Petrology of the Kilpatrick Hills, Dumbartonshire; with Notes on the Scottish Carboniferous Basalts. 'Trans. Glasgow Geol. Soc.' XIV. 219–257. 1913.

—— Variolites from Upper Loch Fyne and Skye. 'Trans. Glasgow Geol. Soc.' XIV. 291–302. 1913.

UPTON, CHARLES. On the Abundant Occurrence of *Involutina liassica* (Jones) in the Lower Lias at Gloucester. 'Proc. Cotteswold Nat. Field Club,' XVIII. 72. 1913.

WADE, Dr. ARTHUR. Glacial Lakes and the Welsh Border Rivers. 'Proc. Liverpool Geol. Soc.' XI. 210–225. 1912.

WARREN, S. HAZZLEDINE. Notes on the Fauna and Flora of the so-called 'Arctic Bed' of the Valley of the Lea at Ponders End. 'Essex Naturalist,' XVII. 36–39. 1912.

WARTH, Dr. H. Classification of Igneous Rocks. 'Proc. Birmingham N. H. Phil. Soc.' XIII. 1–11. 1913.

WINWOOD, Rev. H. H. Well-Sinkings on Lansdown, Bath. 'Proc. Cotteswold Nat. Field Club,' XVIII. 83–87. 1913.

WITHERS, THOMAS H. Cirripedes in the Norwich Museum from the Norfolk Chalk, studied by Darwin. 'Trans. Norfolk and Norwich Nat. Soc.' IX. 308–315. 1912.

WOOD, J. MACKWORTH. Past and Present History of Colchester Corporation Water Works with relation to Underground Water. 'Essex Naturalist,' XVIII. 21–36. 1912.

WOODWARD, Dr. A. SMITH. On the Snout of a Pachycormid Fish (*Protosphyræna stebbingi*) from the Lower Chalk of S. Ferriby, Lincolnshire. 'The Naturalist for 1912,' 329–330. 1912.

WRIGHT, JAMES, jun. On the Crinoids from the Lower Carboniferous Limestones of Invertiel, Fife. 'Trans. Edinburgh Geol. Soc.' x. 49–60. 1912.

Section D.—ZOOLOGY.

ARMISTEAD, WILSON H. The Development of Modern Fish Culture, with specia reference to the Salmonidæ. 'Trans. Dumfriesshire and Galloway N. H. A. Soc.' XXIV. 169–176. 1912.

BARRETT-HAMILTON, G. E. H. The Weight of Irish Hares. 'Irish Naturalist,' XXI. 234. 1912

BARRINGTON, R. M. The Dartford Warbler in Ireland. 'Irish Naturalist,' XXI. 232–234. 1912.

BAYFORD, E. G. Yorkshire Coleoptera in 1912. 'The Naturalist for 1913,' 100–102. 1913.

BELL, J. Bird-nesting in the Isle of Man. 'Proc. Isle of Man N. H. A. Soc.' (N. S.) I. 455–461. 1913.

BELT, ANTHONY. On the Occurrence of *Raia undulata* Lacep. on the Sussex Coast. 'Hastings and East Sussex Naturalist,' II. 8*a*.–8*b*. 1912.

BENNETT, W. H. The Coleoptera of the Hastings District. 'Hastings and East Sussex Naturalist,' II. 21–40. 1912.

BICKERTON, WILLIAM. Notes on Birds observed in Hertfordshire during the year 1910. 'Trans. N. H. S. F. C.' XIV. 271–286. 1912.

BLATHWAYT, Rev. F. L. A Preliminary List of the Lincolnshire Mammalia. 'Trans. Lincolnshire Nat. Union, 1912,' 60–67. 1913.

BLOOMFIELD, Rev. E. N. Annual Notes on the Local Fauna, Flora, &c., for 1911. 'Hastings and East Sussex Naturalist,' II. 1–7. 1912.

BOLAM, GEORGE. Notes on the Natural History of Hornsea Mere. 'The Naturalist for 1913,' 33–71. 1913.

BOOTH, H. B. The Bearded Tit. Experiment at Hornsea Mere. 'The Naturalist for 1912.' 168–170. 1912.

—— Nesting of the Common Gull on the Farne Islands. 'The Naturalist for 1912,' 237. 1912.

BROWN, JAMES MEIKLE. Freshwater Rhizopoda and Heliozoa from Kinder Scout. 'The Naturalist for 1912,' 179–182. 1912.

BRYCE, DAVID. On Five New Species of Bdelloid Rotifera. 'Journal Quekett Mic. Club,' XII. 83–94. 1913.

CARADOC AND SEVERN VALLEY FIELD CLUB. Zoological Notes. 'Record of Bare Facts,' No. 22, 15–24. 1913.

CARTER, A. E. J. A List of Perthshire Diptera (Family Syrphidæ). 'Trans. Perthshire Soc. Nat. Sci.' V. 129–132. 1912.

CLARKE, W. J. Planer's Lamprey near Scarborough. 'The Naturalist for 1912,' 185. 1912.

CLUTTERBUCK, C. GRANVILLE. Long-tailed Ichneumon Fly (*Rhyssa persuasoria*, Linn.) in Gloucestershire. 'Proc. Cotteswold Nat. Field Club,' XVIII. 67–68. 1913.

COLGAN, NATHANIEL. *Cerianthus Lloydii* and *Adamsia palliata* on the Dublin Coast. 'Irish Naturalist,' XXI. 190–192. 1912.

—— Notes on the Development of *Actæonia*. 'Irish Naturalist,' XXI. 225–231. 1912.

—— *Adalaria proxima*, an Addition to the Irish Nudibranch Fauna. 'Irish Naturalist,' XXII. 33–35. 1913.

CRALLAN, Dr. G. E. J. The Island of Jersey from a Natural Science Point of View. 'Proc. Bournemouth Nat. Sci. Soc.' IV. 62–70. 1913.

CURTIS, W. PARKINSON. On Order and Method in forming Collections, with especial reference to Insects and Aves. 'Proc. Bournemouth Nat. Sci. Soc.' IV. 71–88. 1913.

DAY, CYRIL DOUGLAS. The Natural History of Bhompston Pond, near Dorchester. 'Proc. Dorset N. H. A. F. C.' XXXIII. 200–231. 1912.

DENDY, Prof. ARTHUR. The President's Address: By-products of Organic Evolution. 'Journal Quekett Mic. Club,' XII. 65–82. 1913.

DISNEY, H. A. P. Notes on Birds in 1911. 'Report Marlb. Coll. N. H. Soc.' No. 60, 55. 1912.

DONISTHORPE, H. ST. J. K. On some Remarkable Associations between Ants of different Species. 'Proc. Lancashire and Cheshire Entom. Soc.' 1912, 38–56. 1912.

DREYER, Dr. T. F. On the Salivary and Mouth Glands of the Nudibranchiata. 'Trans. Royal Soc. of S. Africa,' III. 139–146. 1913.

FALCONER, WM. The Spiders of Wicken, Cambridge. 'The Naturalist for 1912,' 310–324. 1912.

—— On the Origin of the Araneidal Fauna of Yorkshire. 'The Naturalist for 1913,' 111–114, 131–138. 1913.

FORTUNE, R. Notes on the Farne Islands for 1912. 'The Naturalist for 1913,' 195. 1913.

FOSTER, NEVIN H. Notes on Birds observed at Bundoran. 'Irish Naturalist,' XXI. 218–219. 1912.

FRIEND, Rev. HILDERIC. Some Norfolk Annelids. 'Trans. Norfolk and Norwich Nat. Soc.' IX. 394–405. 1912.

—— Irish Oligochæts. 'Irish Naturalist,' XXI. 171–174. 1912; XXII. 7–11. 1913.

—— Annelid Hunting in Notts. (Second Paper.) 'Report Nottingham Nat. Soc. 1911–12,' 50–64. 1913.

GEORGE, C. F. Some British Earthmites. 'The Naturalist for 1912,' 183–184; 236–237. 1912.

—— *Ritteria nemorum* Koch. 'The Naturalist for 1913,' 109–110. 1913.

—— *Gamasus ignotus* n.sp. in Lincolnshire. 'The Naturalist for 1913,' 139–140. 1913.

—— The Mites known as Rhagadia. 'The Naturalist for 1913,' 196–197. 1913.

GILCHRIST, Dr. J. D. F. Description of a new Species of Sting Ray (*Trygon*) from South Africa. 'Trans. Royal Soc. of S. Africa,' III. 33–34. 1913.

GLADSTONE, HUGH S. Addenda and Corrigenda to the 'Birds of Dumfriesshire. 'Trans. Dumfriesshire and Galloway N. H. A. Soc.' XXIV. 13–38. 1912.

HAIGH-LUMBY, A. Vertebrate Zoology in Yorkshire. 'The Naturalist for 1913,' 149–150. 1913.

HALLETT, H. M. A List of the *Hymenoptera aculeata* recorded for the County of Glamorgan. 'Trans. Cardiff Nat. Soc.' XLIV. 92–99. 1912.

HAMMOND, JOHN. An Investigation concerning the Food of certain Birds. 'Trans. Norfolk and Norwich Nat. Soc.' IX. 316–327. 1912.

HEWITT, JOHN, and PAUL A. METHUEN. Descriptions of some new Batrachia and Lacertilia from South Africa. 'Trans. Royal Soc. of S. Africa,' III. 107–111. 1913.

—— and J. H. POWER. A List of South African Lacertilia, Ophidia, and Batrachia in the McGregor Museum, Kimberley; with Field Notes on various Species. 'Trans. Royal Soc. of S. Africa,' III. 147–176. 1913.

HINTON, MARTIN C. On the Remains of Vertebrate Animals found in the Middens of Rayleigh Castle, Essex. 'Essex Naturalist,' XVII. 16–21. 1912.

HORRELL, E. CHARLES. Notes on the Beetles of Scarborough. 'The Naturalist for 1913,' 103–104. 1913.

HUDD, ALFRED E. (Editor.) Somerset Lepidoptera. An Appendix to the County List printed in the 'Victoria County History of Somerset,' Vol. I. 'Proc. Somersetshire Arch. N. H. Soc.' LVIII. 105–113. 1913.

JACKSON, Dr. A. RANDELL. Notes on Collecting and Preserving Spiders. 'Proc. Isle of Man N. H. A. Soc.' (N.S.) I. 503–508. 1913.

—— On some new and obscure British Spiders. 'Report Nottingham Nat. Soc. 1911–12,' 20–49. 1913.

JOHNSON, Rev. W. F. Entomological Notes from Ulster. 'Irish Naturalist,' XXI. 131–133. 1912.

LACE, RICHARD. The Biological Station at Port Erin and its Nature Study Classes. 'Proc. Isle of Man N. H. A. Soc.' (N.S.) I. 463–467. 1913.

LEWIS, R. T. Note on *Solpura ferox*. 'Journal Quekett Mic. Club,' XI. 507–510. 1912.

M'GOWAN, BERTRAM. A List of the Coleoptera of the Solway District; I. To the End of the Carabidæ. 'Trans. Dumfriesshire and Galloway N. H. A. Soc.' XXIV. 271.

MASON, G. W. The Lepidoptera of Lincolnshire. 'Trans. Lincolnshire Nat. Union 1912,' 59. 1913.

MEYRICK, E. Report of the Entomological Section. 'Report Marlb. Coll. N. H. Soc.' No. 60, 36–44. 1912.

—— Ornithological List. 'Report Marlb. Coll. N. H. Soc.' No. 60, 45–47. 1912.

MEYRICK, E. Hand List of Lepidoptera of the District. 'Report Marlb. Coll. N. H. Soc.' No. 60, 63–96. 1912.
MOFFAT, C. B. Bees and Flowers. 'Irish Naturalist,' XXII. 65–74. 1913.
MORLEY, B. *Xanthia aurago* in the West Riding of Yorkshire. 'The Naturalist for 1912,' 208–209. 1912.
MORLEY, CLAUDE. Ichneumons. 'Proc. Lancashire and Cheshire Entom. Soc.' 1912, 26–37. 1912.
NICHOLSON, Dr. G. W. Some Additional Records of Irish Beetles, chiefly from Co. Meath. 'Irish Naturalist,' XXII. 49–50. 1913.
OLDHAM, CHARLES. Report on Land and Freshwater Mollusca observed in Hertfordshire in 1910. 'Trans. Herts N. H. S. F. C.' XIV. 287–290. 1912.
—— *Nycteribia pedicularia* Latreille (=*N. latreillei* Leach) in Hertfordshire. 'Trans. Herts N. H. S. F. C.' XIV. 290. 1912.
—— On the Occurrence of *Chernes godfreyi* Kew, and other False Scorpions in Hertfordshire. 'Trans. Herts. N. H. S. F. C.' XIV. 299–300. 1912.
—— Daubenton's Bat, *Myotis daubentoni* (Kuhl), in Hertfordshire. 'Trans. Herts N. H. S. F. C.' XIV. 300. 1912.
ORTON, Prof. KENNEDY. The Birds of Puffin Island. 'Proc. Llandudno and District Field Club,' V. 40–45. 1913.
PACK-BERESFORD, D. R., and NEVIN H. FOSTER. Additions to the Distributional Records of Woodlice in Ireland till the end of 1912. 'Irish Naturalist,' XXII. 45–48. 1913.
PATTEN, Prof. C. J. Wrens on Migration observed at the Tuskar Rock and Lighthouse. 'Irish Naturalist,' XXI. 125–130. 1912.
—— Grasshopper Warblers on Migration observed at the Tuskar Lighthouse. 'Irish Naturalist,' XXI. 137–142. 1912.
—— Rock-Pipits on Migration observed at the Tuskar Rock. 'Irish Naturalist,' XXI. 164–170. 1912.
—— Spotted Flycatchers on Migration observed at the Tuskar Rock and Lighthouse. 'Irish Naturalist,' XXI. 193–200. 1912.
—— Discovery of the Tree-Pipit on the Tuskar Rock, Co. Wexford. 'Irish Naturalist,' XXI. 209–213. 1912.
PATTERSON, ARTHUR H. Notes on the Whales of Norfolk. 'Trans. Norfolk and Norwich Nat. Soc.' IX. 300–307. 1912.
—— Natural History Notes from Yarmouth. 'Trans. Norfolk and Norwich Nat. Soc.' IX. 455–458. 1912.
PENTLAND, G. H. Notes on the Increase and Decrease of some Mammals, Birds, and Insects in the County of Louth during the last fifty years. 'Irish Naturalist,' XXI. 145–148. 1912.
PICKARD-CAMBRIDGE, Rev. O. On New and Rare Arachnids noted and observed in 1911. 'Proc. Dorset N. H. A. F. C.' XXXIII. 70–95. 1912.
PITT, Miss F. The Badger: a Creature of the Night. 'Trans. Caradoc and Severn Valley F. C.,' V. 302–313. 1913.
POPPLE, EDWARD. Some Irish Entomostraca. 'Irish Naturalist,' XXI. 220–221. 1912.
PROGER, T. W., and D. R. PATERSON. Ornithological Notes. 'Trans. Cardiff Nat. Soc.' XLIV. 101–105. 1912.
RALFE, P. G. Bird Life in the Isle of Man: a Comparison with the Neighbouring Countries. 'Proc. Isle of Man N. H. A. Soc.' (N.S.) I. 427–436. 1913.
—— Sea-bird Life on our South-Western Coast. 'Proc. Isle of Man' (N.S.) I. 495–501. 1913.
RICHARDSON, NELSON M. Anniversary Address. 'Proc. Dorset N. H. A. F. C.' XXXIII. 1–21. 1912.
ROBSON, JOHN E. A Catalogue of the Lepidoptera of Northumberland, Durham, and Newcastle-upon-Tyne. Vol. II., Micro-Lepidoptera. 'Trans. Northumberland, Durham, and Newcastle-upon-Tyne Nat. Hist. Soc.' XV. iii.–vi. 107–289. 1913.
ROUSSELET, CHARLES F. The Rotifera of Devil's Lake, with Description of a new Brachionus. 'Journal Quekett Mic. Club,' XII. 57–64. 1913.
SCHLESCH, H. A. The Distribution of *Helix* (*Acanthinula*) *lamellata* Jeffr. 'The Naturalist for 1912,' 340. 1912.
SCOURFIELD, D. J. Entomostraca from 'The Warren,' Folkestone. 'South-Eastern Naturalist for 1912,' 57–58. 1912.
SELBIE, C. M. Some New Irish Myriapods. 'Irish Naturalist,' XXI. 113–115. 1912.

SELOUS, EDMUND. The Nuptial Habits of the Black Cock. 'The Naturalist for 1913,' 96–98. 1913.
SICH, ALFRED. Lepidopterous Case-bearers. 'South-Eastern Naturalist for 1912,' 32–38. 1912.
SMITH, S. H. Bird Notes from the York District. 'The Naturalist for 1912,' 339. 1912.
STELFOX, A. W. The Terrestrial Mollusca of the Great Blasket and Beginish. 'Irish Naturalist,' XXI. 185–190. 1912.
STEVENS, JOHN. Note on *Proales* (*Notommata*) *gigantea* Glascott, a Rotifer Parasitic in the Egg of the Water-snail. 'Journal Quekett Mic. Club,' XI. 481–486. 1912.
TAYLOR, FRED. Notes on the Land and Freshwater Mollusca of the Isle of Man. 'Proc. Isle of Man N. H. A. Soc.' (N.S.) I. 509–513. 1913.
THEOBALD, FRED. V. The Aphididæ of the Hastings District. 'Hastings and East Sussex Naturalist,' II. 9–20. 1912.
THORNLEY, Rev. A., and W. WALLACE. Lincolnshire Coleoptera: Part VI. 'Trans. Lincolnshire Nat. Union, 1912,' 38–58. 1913.
TICEHURST, CLAUD B. Migration and other Ornithological Notes from Lowestoft District, June 30, 1910, to June 30, 1911. 'Trans. Norfolk and Norwich Nat. Soc.' IX. 406–427. 1912
TOMLIN, J. R. LE B. Report on Coleoptera. 'Proc. Lancashire and Cheshire Entom. Soc. 1912,' 23–25. 1912.
TURNER, Miss E. L. The Return of the Bittern. 'Trans. Norfolk and Norwich Nat. Soc.' IX. 433–436. 1912.
WAILES, G. H. Freshwater Rhizopoda from the North and West Ridings of Yorkshire. 'The Naturalist for 1913,' 144–148. 1913.
WALKER, J. J. Interim Report on Coleoptera. 'Report Ashmolean Nat. Hist. Soc. 1912,' 43. 1913.
WALLACE, W. Presidential Address: The Emotions and the Senses of Insects. 'Trans. Lincolnshire Nat. Union, 1912,' 9–20. 1913.
WALLIS, EUSTACE F. Further Notes on the Lepidoptera of Northamptonshire. 'Journal Northants N. H. Soc.' XVI. 297–299. 1913.
WARREN, ROBERT. Wild Cats in Ireland. 'Irish Naturalist,' XXII. 94–96. 1913.
WATERSTON, JAMES. Notes on some Ectoparasites in the Museum, Perth. 'Trans. Perthshire Soc. Nat. Sci.' V. 123–128. 1912.
WHELLENS, W. H. Destructive Forest Insects of Dumfriesshire. 'Trans. Dumfriesshire and Galloway N. H. A. Soc.' XXIV. 260–269. 1912.
WHITAKER, ARTHUR. Notes on the Habits of Bats. 'The Naturalist for 1912,' 9–12. 1912.
WHITE, JOHN. The Fauna of Gibraltar. 'Selborne Mag.' XXIII. 97–101, 139–144. 1912.
WHITEHEAD, HENRY. Some Notes on British Freshwater Rhabdocœlida—a Group of Turbellaria. 'Journal Quekett Mic. Club,' XII. 45–56. 1913.
WILSON, ALEX. The Birds of Nairn. 'Trans. Edinburgh F. N. Mic. Soc.' VI. 400–413. 1912.
WINTER, W. P. Arachnida at Tebay. 'The Naturalist for 1912,' 304–305. 1912.
WITHERBY, H. F. The Autumn Migration of Swallows at Rosslare Harbour. 'Irish Naturalist,' XXI. 143–144. 1912.
WOODS, F. H. Yorkshire Marine Biology Committee at Robin Hood's Bay, Oct. 12–14. 'The Naturalist for 1912,' 368–370. 1912.
WOOLNER, C. G. Malacological Report. 'Report Marlb. Coll. N. H. Soc.' No. 60, 49–50. 1912.
WYLIE, W. A. List of the Macro-Lepidoptera of the Kinfauns District, with a general description of some of the rarer forms. 'Trans. Perthshire Soc. Nat. Sci.' V. 114–123. 1912.
WYSE, L. H. BONAPARTE. Lepidoptera and Coleoptera from Co. Kerry. 'Irish Naturalist,' XXII. 75–76. 1913.

Section E.—GEOGRAPHY.

BELLAMY, C. H. Atlantic to Pacific, across the Canadian Rockies. 'Journal Manchester Geog. Soc.' XXVII. 136–140. 1912.
BELLOWS, WILLIAM. The Island of Jan Meyen. 'Proc. Cotteswold Nat. Field Club,' XVII. 333–340. 1912.

FALCONER, Dr. J. D. Northern Nigeria and its Peoples. 'Proc. Glasgow Royal Phil. Soc.' XLIII. 121–138. 1912.

KALISH, RICHARD. China, Past and Present. 'Journal Manchester Geog. Soc.' XXVII. 109–135. 1912.

LARPENT, G. DE H. Rhodesia Past and Present. 'Trans. Liverpool Geog. Soc. 1912,' 11–17. 1913; 'Journal Manchester Geog. Soc.' XXVIII. 30–36. 1913.

MACKENZIE, DONALD. A Journey through Nine Moorish Provinces. 'Journal Manchester Geog. Soc.' XXVII. 101–108. 1912.

QUALTROUGH, Miss KATE. The Pathways of the Past. 'Journal Manchester Geog. Soc.' XXVIII. 4–24. 1913.

SMITH, RUPERT. Notes on a Visit to Egypt. 'Trans. Edinburgh F. N. Mic. Soc.' VI. 416–422. 1912.

Section F.—ECONOMIC SCIENCE AND STATISTICS.

BICKERDIKE, C. F. International Comparisons of Labour Conditions. 'Trans. Manchester Stat. Soc. 1911–1912,' 61–83. 1912.

BORREN, DAVID (Midland Inst. Eng.). The Taxation of Mines in various Countries. 'Trans. Inst. Min. Eng.' XLIV. 560–613. 1913.

CHART, D. A. The 'General Strike' as a Labour Weapon. 'Journal Stat. Soc. Ireland,' XII. 559–568. 1912.

COLLINS, J. H. Some Historical and other Notices of Mining in the Northern Part of the Parish of St. Agnes. 'Journal Royal Cornwall Poly. Soc.' (N.S.), 2, 64–74. 1912.

DAWSON, CHARLES. The Industrial Progress of Belgium: An Object Lesson for Ireland. 'Journal Stat. Soc. Ireland,' XII. 595–608. 1912.

EDWARDS, W. DUDLEY. The National Insurance Act, 1911 (Part I.), as applying to Ireland. 'Journal Stat. Soc. Ireland,' XII. 569–582. 1912.

FINLAY, Rev. T. A. Presidential Address: Labour Associations in their relation to the State. 'Journal Stat. Soc. Ireland,' XII. 511–522. 1912.

FRASER, D. DRUMMOND. The Problem of the Gold Reserve. 'Trans. Manchester Stat. Soc. 1911–1912,' 1–23. 1912.

GAMMELL, SYDNEY J. Scotch Forestry: its Economic Aspect. 'Proc. Glasgow Royal Phil. Soc.' XLIII. 46–55. 1912.

GLAISTER, Prof. JOHN. The Future of the Race: A Study in Present Day Aspects of Social Binomics. 'Proc. Glasgow Royal Phil. Soc.' XLIII. 1–45. 1912.

GREENWELL, GEORGE HAROLD (N. Eng. Inst. Eng.). The Jherria Coalfield (India) and its future Development. 'Trans. Inst. Min. Eng.' XLV. 88–105. 1913.

GREGORY, Prof. J. W. The Employment of White Labour in the Sugar Plantations of Queensland. 'Proc. Glasgow Royal Phil. Soc.' XLIII. 182–194. 1912.

HIRST, F. W. The Theory and Finance of Modern Armaments. 'Trans. Manchester Stat. Soc.' 1911–1912, 25–36. 1912.

PATON, J. L. The Adolescence of the Working Lad in Industrial Towns. 'Trans. Manchester Stat. Soc. 1911–1912,' 85–99. 1912.

SMITH, ALEXANDER. Recent Legislation in relation to Lands and Mines. 'Trans. Inst. Min. Eng.' XLIV. 722–731. 1913.

STANUELL, CHARLES A. The Improvement of Dublin Harbour. 'Journal Stat. Soc. Ireland,' XII. 546–558. 1912.

WELTON, THOS. A. On the Marriage Rate since 1880 in England and Wales. 'Trans. Manchester Stat. Soc.' 1911–1912, xvii.–xxvi. 1912.

WIGG, T. J. Notes on the Herring Fishery of 1911. 'Trans. Norfolk and Norwich Nat. Soc.' 428–431. 1912.

WILLIAMS, R. The Organisation of the Casual Labour Market. 'Trans. Manchester Stat. Soc. 1911–1912,' 37–60. 1912.

Section G.—ENGINEERING.

ABELL, Prof. W. S. The Safety of Ships at Sea. 'Trans. Liverpool Eng. Soc. XXXIII. 88–99. 1913.

ANDERSON, W. T. (Manchester Geol. Min. Soc.). Colliery Cables, 'Trans. Inst. Min. Eng.' XLV. 122–143. 1913.

BARBER, WILLIAM (N. Staff. Inst. Eng.). Rearer Workings at Podmore Hall Collieries, with special reference to alluvium saturated with water. 'Trans. Inst. Min. Eng.' XLV. 373–381. 1913.

Bogle, J. M. Linton. Tramway Rails and Rail Wear. 'Trans. Liverpool Eng. Soc.' xxxiii. 359–380. 1912.
Bowen, David, and Walter E. French. Safety Devices in connection with Electrical Machinery and Apparatus for Coal Mines. 'Trans. Inst. Min. Eng.' xliii. 459–493. 1912.
Bradshaw, Hubert (S. Staffs. and Warw. Inst. Eng.). Suggestions on the Development of New Colliery Districts, with special reference to the Support of the Surface. 'Trans. Inst. Min. Eng.' xlv. 171–181. 1913.
Briggs, Henry (Min. Inst. Scotland). Improvements relating to the Anemometer and Hygrometer. 'Trans. Inst. Min. Eng.' xlv. 59–64. 1913.
Brown, A. W. Electrically-driven Winding-engines in South Africa. 'Trans. Inst. Min. Eng.' xliv. 186–212. 1912.
Bruce, W. J. Willett. Inaugural Address. [Marine Engineering.] 'Trans. Liverpool Eng. Soc.' xxxiii. 1–17. 1912.
Cadman, Prof. John (S. Staffs. and Warw. Inst. Eng.). Mine-rescue Appliances: A Danger occurring in the use of Apparatus in which an Injector is employed. 'Trans. Inst. Min. Eng.' xliv. 463–467. 1913.
Caldwell, George S. (Manchester Geol. Min. Soc.). Experiences on a Chinese Coal field. 'Trans. Inst. Min. Eng.' xliii. 361–369. 1912.
Charlton, W. (S. Staffs. and Warw. Inst. Eng.). Modern Ventilating Machines. 'Trans. Inst. Min. Eng.' xliii. 338–347. 1912.
Elliott, John. Some Recent Developments in Condensing Machinery. 'Trans Liverpool Eng. Soc.' xxxiii. 238–260. 1912.
Garforth, William Edward. Presidential Address: The Danger of Coal-dust in Mines, and the Means of minimising this Danger by Stone-dusting. 'Trans. Inst. Min. Eng.' xliii. 406–425. 1912.
Given, E. C. Anti-Rolling Devices for Ships. 'Trans. Liverpool Eng. Soc.' xxxiii. 109–125. 1912.
Hailwood, E. A. (N. England Inst. Eng.). The Hailwood Gas Cap Observation Machine. 'Trans. Inst. Min. Eng.' xliv. 503–511. 1913.
Harger, Dr. John (Manchester Geol. Min. Soc.). Gob-fires and the Prevention of Gob-fires in Mines. 'Trans. Inst. Min. Eng.' xliv. 318–337. 1913.
—— Fire-damp in Coal Mines. 'Trans. Inst. Min. Eng.' xlv. 269–278. 1913.
Hepplewhite, W. Hutton (Mid. Counties Inst. Eng.). Presidential Address. 'Trans. Inst. Min. Eng.' xliv. 114–121. 1912.
Herzfeld, Dr. R. (Midland Inst. Eng.). Some Novel Devices in connection with Electrical Pumping Installation in Mines. 'Trans. Inst. Mid. Eng.' xliv. 615–621. 1913.
Jackson, Douglas (Min. Inst. Scotland). A Method of Capping Winding-ropes 'Trans. Inst. Min. Eng.' xliii. 331–333. 1912.
Jenkins, Harold C. (Midland Inst. Eng.). Some recent Experiments with Internal Pressures in Pneumatophors. 'Trans. Inst. Min. Eng.' xlv. 230–241. 1913.
Jones, W. Hemming. The Brocklebank Dock Improvements on the Mersey Dock Estate. 'Trans. Liverpool Eng. Soc.' xxxiii. 164–190. 1912.
King, J. S. (Manchester Geol. Min. Soc.). The Prevention of Misfires and of Accidents in Blasting Operations. 'Trans. Inst. Min. Eng.' xlv. 2–10. 1913.
Knox, George (Manchester Geol. Min. Soc.). The Relation between Subsidence and Packing, with special reference to the Hydraulic Stowing of Goaves. 'Trans. Inst. Min. Eng.' xliv. 527–542. 1913.
—— The Hydraulic Stowing of Goaves. 'Trans. Inst. Min. Eng.' xlv. 13–25. 1913.
Lloyd, W. D. (Midland Inst. Eng.). Some Experiences with Winding-ropes and Capels. 'Trans. Inst. Min. Eng.' xliv. 56–71. 1912.
McLuckie, John (Min. Inst. Scotland). The Use of Old Wire Ropes in timbering Roadways. 'Trans. Inst. Min. Eng.' xliv. 255–258. 1912.
Marchant, Prof. E. W. The Function of the Laboratory in the Training of an Engineer, with a short account of some new Laboratory Equipment. 'Trans. Liverpool Eng. Soc.' xxxiii. 19–37. 1912.
Mills, Frederick P. (Manchester Geol. Min. Soc.). A New Mining Dial. 'Trans. Inst. Min. Eng.' xliv. 553–558. 1913.
Mining Institute of Scotland, The. Report by the Committee appointed to test Mr. Henry Briggs's conclusions in his paper on 'Testing for Fire-damp and Black-damp by means of a Safety-lamp.' 'Trans. Inst. Min. Eng.' xlv. 390–392. 1913.

MOWAT, DAVID M. (Min. Inst. Scotland). Facts and Theories relating to Fans. 'Trans. Inst. Min. Eng.' XLIV. 92–103. 1912.

NEWALL, J. M. Communication between the Engine Room and the Bridge of Steam-ships, and some methods of controlling the same. 'Trans. Liverpool Eng. Soc.' XXXIII. 201–227. 1912.

PICKERING, W. H., and BASIL H. PICKERING. Why Leave Shaft Pillars? 'Trans. Inst. Min. Eng.' XLIII. 428–435. 1912.

ROWAN, HENRY (Min. Inst. Scotland). Underground Fires. 'Trans. Inst. Min. Eng.' XLV. 396–402. 1913.

SAINT, T. A. (N. England Inst. Eng.). The Lighting Efficiency of Safety-lamps. 'Trans. Inst. Min. Eng.' XLV. 327–336. 1913.

SALT, W. G., and A. L. LOVATT (N. Staffs. Inst. Eng.). Notes on Haulage Clips in use in North Staffordshire. 'Trans. Inst. Min. Eng.' XLIV. 402–417. 1913.

SMITH, J. RENEY. Further Notes on Marine Boiler Failures. 'Trans. Liverpoo Eng. Soc.' XXXIII. 334–346. 1912.

SOPWITH S. F. (S. Staffs. and Warw. Inst. Eng.). The Electrification of Cannock Chase Colliery. Trans. Inst. Min. Eng.' XLV. 350–359. 1913.

SPENCE, WILFRID L. A Rope-driven Coal-cutter. 'Trans. Inst. Min. Eng.' XLIII. 516–527. 1912.

STIRLING, JOHN T., and Prof. JOHN CADMAN. The Bellevue Explosions, Alberta, Canada: An Account of, and subsequent Investigations concerning, three Explosions produced by Sparks from Falls of Roofs. 'Trans. Inst. Min. Eng.' XLIV. 740–756. 1913.

STUBBS, THOMAS (Midland Inst. Eng.). Notes on Gob-fires near Ashby-de-la-Zouch, Leicestershire. 'Trans. Inst. Min. Eng.' XLIV. 440–448. 1913.

THOMPSON, ALFRED (Midland Inst. Eng.). Maltby Main Colliery. 'Trans. Inst. Min. Eng.' XLIV. 33–47. 1912.

THORNTON, Prof. W. M. (N. England Inst. Eng.). The Ignition of Coal-gas and Methane by Momentary Electric Arcs. 'Trans. Inst. Min. Eng.' XLIV. 145–174. 1912.

WALKER, GEORGE BLAKE (Midland Inst. Eng.). The Generation and Use of Compressed Air for Mining. 'Trans. Inst. Min. Eng.' XLIV. 629–689. 1913.

WALKER, R. J. The Marine Steam Turbine. 'Trans. Liverpool Eng. Soc.' XXXIII. 137–155. 1912.

WATSON, JOHN (Min. Inst. Scotland). The Testing of Fans: a Plea for Standardised Test Conditions. 'Trans. Inst. Min. Eng.' XLV. 403–408. 1913.

WINDELER, GEORGE E. The Diesel Engine. Its Application to Land and Marine Work. 'Trans. Liverpool Eng. Soc.' XXXIII. 269–292. 1912.

Section H.—ANTHROPOLOGY.

BULLEID, ARTHUR, and H. St. GEORGE GRAY. Meare Lake Village. 'Proc. Somersetshire Arch. N. H. Soc.' LVIII. 38–41. 1913.

CARTER, G. S. On Pottery found near Four Mill Clump on the Marlborough Downs. 'Report Marlb. Coll. N. H. Soc.' No. 60, 51–52. 1912.

CLARKE, W. G. Implements of Sub-Crag Man in Norfolk. 'Proc. Prehistoric Soc. of East Anglia,' I. 160–168. 1913.

CURRLÉ, Miss L., with Additional Notes by L. Péringuey. Notes on Namaqualand Bushmen. 'Trans. Royal Soc. of S. Africa,' III. 113–120. 1913.

KEITH, Dr. ARTHUR. Description of the Ipswich Skeleton. 'Proc. Prehistoric Soc. of East Anglia,' I. 203–209. 1912.

KERMODE, P. M. C. The Celtic Tribal System in the Isle of Man. 'Proc. Isle of Man N. H. A. Soc.' (N.S.) I. 477–483. 1913.

LYELL, Dr. JOHN H. A Pioneer in Criminology: Notes on the Work of James Bruce Thomson of Perth. 'Trans. Perthshire Soc. Nat. Sci.' V. 103–114. 1912.

MACDONALD, Dr. DAVID. Pigmentation of the Hair and Eyes of Children suffering from the Acute Fevers: its Effect on Susceptibility, Recuperative Power, and Race Selection. 'Proc. Glasgow Royal Phil. Soc.' XLIII. 56–61. 1912.

MEYRICK, E. Anthropometrical Report. 'Report Marlb. Coll. N. H. Soc.' No. 60 119–145. 1912.

MOIR, J. REID. The Natural Fracture of Flint and its Bearing upon Rudimentary Flint Implements. 'Proc. Prehistoric Soc. of East Anglia,' I. 171–184. 1913.

—— The Occurrence of a Human Skeleton in a Glacial Deposit at Ipswich. 'Proc. Prehistoric Soc. of East Anglia,' I. 194–202. 1912.

STURGE, Dr. W. ALLEN. The Patina of Flint Implements. 'Proc. Prehistoric Soc. of East Anglia,' I. 140–157. 1912.

—— Implements of the later Palæolithic 'Cave' Periods in East Anglia. 'Proc. Prehistoric Soc. of East Anglia,' I. 210–232. 1912.

TOMS, HERBERT S. Notes on some Surveys of Valley Entrenchments in the Piddletrenthide District, Central Dorset. 'Proc. Dorset N. H. A. F. C.' XXXIII. 34–44. 1912.

UNDERWOOD, Lieut.-Col. W. Recent Discoveries in Palethnology and the Works of Early Man. 'Proc. Prehistoric Soc. of East Anglia,' I. 135–139. 1913.

WARREN, S. HAZZLEDINE. Palæolithic Remains from Clacton-on-Sea, Essex. 'Essex Naturalist,' XVII. 15. 1912.

Section I.—PHYSIOLOGY.

BUTCHER, W. DEANE. Presidential Address: The Anatomical Basis of Education 'Trans. Ealing Sci. Mic. Soc., 1911–1912,' 1–5. 1912.

JOLLY, W. A. Positive Electrical Variation in Isolated Nerve. 'Trans. Royal Soc. of S. Africa,' III. 23–32. 1913.

LLEWELLYN, Dr. T. LISTER (S. Staffs. and Warw. Inst. Eng.). Illumination at the Coal-face, with special reference to the Incidence of Miners' Nystagmus. 'Trans. Inst. Min. Eng.' XLIV. 273–287. 1912.

ROSS, Dr. J. MAXWELL. The Weather of 1911 in relation to Health. 'Trans. Dumfriesshire and Galloway N. H. A. Soc.' XXIV. 201–209. 1912.

STORY, J. B. Medical Inspection of Schools and School Children. 'Journal Stat. Soc. Ireland,' XII. 523–545. 1912.

WAGER, HORACE A. Respiration and Cell Energy. Trans. 'Royal Soc. of S. Africa,' II. 405–418. 1912.

WALKER, J. A short Note on the Occurrence of a Leucocytozoon Infection-Host: The Ostrich. 'Trans. Royal Soc. of S. Africa,' III. 35–38. 1913.

Section K.—BOTANY.

ADAMS, J. Some New Localities for Marine Algæ. 'Irish Naturalist,' XXII. 12–13. 1913.

ARNOTT, S. Some Local and other Plant Names. 'Trans. Dumfriesshire and Galloway N. H. A. Soc.' XXIV. 223–228. 1912.

BALE, W. M. Notes on some of the Discoid Diatoms. 'Journal Quekett Mic. Club,' XII. 17–44. 1913.

BARCLAY, W. The Additions to the List of Perthshire Plants since the publication of Dr. White's 'Flora.' 'Proc. Perthshire Soc. Nat. Sci.' V. cxlviii.–clxv. 1912.

BARRETT, W. BOWLES. Contributions to a Flora of Portland, with special reference to *Limonium recurvum*, C. E. Salmon. 'Proc. Dorset N. H. A. F. C.' XXXIII. 96–143. 1912.

BEDFORD, E. J. Notes on Two Orchids new to East Sussex. 'Trans. Eastbourne N. H., Sci., and Lit. Soc.' (N.S.) II. 50–52. 1912.

BENNETT, ARTHUR. *Stelleria Dilleniana* in Norfolk. Trans. Norfolk and Norwich Nat. Soc. IX. 315–316. 1912.

—— Notes on the Twenty-eight Species of East Anglian Plants that have been passed in review in the 'Transactions' from Vol. VI. to Vol. VIII., 1899–1909. 'Trans. Norfolk and Norwich Nat. Soc.' IX. 436–454. 1912.

—— *Utricularia ochroleuca* Hartm. in Yorkshire. 'The Naturalist for 1913, 19. 1913.

—— *Malaxis paludosa* L. in Cheshire. 'The Naturalist for 1913,' 127. 1913.

BIRD, Rev. M. C. H. Acorns. 'Trans. Norfolk and Norwich Nat. Soc.' IX. 327–340. 1912.

BOUDIER, EM. Sur deux nouvelles espèces de Discomycètes d'Angleterre. 'Trans. British Mycological Soc.' IV. 62–63. 1913.

BOYD, D. A. Notes on Parasitic Ascomycetes: Part II. 'Trans. Edinburgh F. N. Mic. Soc.' VI. 431–438. 1912.

—— Notes on the Fungus-Flora of the Moray District. 'Trans. British Mycologica Soc.' IV. 66–73. 1913.

BRITISH MYCOLOGICAL SOCIETY. Report of the Worcester Spring Foray, May 24–28, 1912, and complete List of the Fungi and Mycetozoa gathered during the Foray. 'Trans. British Mycological Soc.' IV. 11–21. 1913.

—— Report of the Forres Foray, Sept. 12–19, 1912, and complete List of Fung gathered during the Foray. 'Trans. British Mycological Soc.' IV. 22–37. 1913.

Buller, Prof. A. H. R. Upon the Retention of Vitality by Dried Fruit-bodies of certain Hymenomycetes, including an account of an Experiment with Liquid Air. 'Trans. British Mycological Soc.' iv. 106–112. 1913.

Burtt-Davy, Joseph. Notes on the Genus *Ficus* (Tourn.), Linn. 'Trans. Royal Soc. of S. Africa,' ii. 365–368. 1912.

—— A New Species of *Mesembrianthemum* from the Transvaal. 'Trans. Royal Soc. of S. Africa,' ii. 369–371. 1912.

Caradoc and Severn Valley Field Club. Botanical Notes, 1912. 'Record of Bare Facts,' No. 22, 5–14. 1913.

Clarke, Alfred. The Genus Tricoloma. 'The Naturalist for 1912,' 364–365. 1912.

Colgan, N. Further Notes on the Burnt-Ground Flora of Killiney Hill. 'Irish Naturalist,' xxii. 85–93. 1913.

Cotton, A. D. *Colpomenia sinuosa*, a New British Seaweed. 'Proc. Bournemouth Nat. Sci. Soc.' iv. 61–62. 1913.

Crossland, C. *Phæangella Smithiana* Boud. (=*Pseudo-Phacidium Smithianum* Boud.) in Yorkshire. 'The Naturalist for 1912,' 206–207. 1912.

—— Mycological Meeting at Sandsend. 'The Naturalist for 1913,' 21–28. 1913.

—— Recently discovered Fungi in Yorkshire. 'The Naturalist for 1913,' 173–179. 1913.

Dixon, H. N. Northamptonshire Hepaticæ. 'Journal Northants N. H. Soc.' xvi. 295. 1913.

Druce, G. Claridge. Notes on Irish Plants. 'Irish Naturalist,' xxi. 235–240. 1912.

—— Northamptonshire Botanologia. 'Journal Northants N. H. Soc.' xvi. 183–214. 1912.

—— Northamptonshire Plant Notes for 1911 and 1912. 'Journal Northants N. H Soc.' xvi. 291–295. 1913.

Dümmer, R. A Revision of the Genus *Alepidea* Delaroche. 'Trans. Royal Soc. of S. Africa,' iii. 1–21. 1913.

Elliott, Dr. Jessie S. B. *Sigmoideomyces clathroides*: a New Species of Fungus. 'Trans. British Mycological Soc.' iv. 121–124. 1913.

Ellis, John W. New British Fungi. 'Trans. British Mycological Soc.' iv. 124–126. 1913.

Griffin, W. H. The Alien Flora of Britain. 'South-Eastern Naturalist for 1912,' 24–31. 1912.

Grove, W. B. Irish Fungi. 'Irish Naturalist,' xxi. 111–112. 1912.

Hawley, Sir H. C. The Pyrenomycetes and some Problems they suggest. 'The Naturalist for 1912,' 341–343. 1912.

Haydon, Walter T. Presidential Address: Henry David Thoreau, Poet-Naturalist. 'Proc. Liverpool Bot. Soc. 1910–11,' 55–85. 1912.

Highfield, E. G. The Structure of a Garlic Bulb. 'The Naturalist for 1912,' 331–336. 1912.

Holt, G. A. Additions to Manx Grasses. 'Proc. Isle of Man N. H. A. Soc.' (n.s.) i. 445–446. 1913.

Ingham, Wm. A new British Hepatic (*Cephaloziella pulchelia* C. Jens.). 'The Naturalist for 1912,' 367. 1912.

Jackson, A. Bruce. The Bearberry on the Southern Pennines. 'The Naturalist for 1913,' 95. 1913.

Johnson, J. W. Haigh. The Composition of Peat and Ecological Methods. 'The Naturalist for 1913,' 169–171. 1913.

Knight, H. H. The Distribution of Calluna on the Cotteswolds. 'Proc. Cotteswold Nat. Field Club,' xviii. 69–71. 1913.

Lee, the late P. Fox. Second Supplement to the Flora of Dewsbury and District. 'The Naturalist for 1912,' 238–244, 285–289, 306–309. 1912.

Lett, Rev. Canon W. H. Botanists of the North of Ireland. 'Irish Naturalist, xxii. 21–33. 1913.

Lindsay, John. The Elimination of Algæ in Lochs and Ponds. 'Trans. Edinburgh F. N. Mic. Soc.' vi. 422–431. 1912.

Lister, Miss Gulielma. Mycetozoa found during the Fungus Foray in the Forres District, Sept. 12–20, 1912, with the Description of a New Species. 'Trans. British Mycological Soc.' iv. 38–44. 1913.

—— Presidéntial Address: The Past Students of Mycetozoa and their Work. 'Trans. British Mycological Soc.' iv. 44–61. 1913.

MARLOTH, Dr. R. Some new or little-known South African Succulents. Part V. 'Trans. Royal Soc. of S. Africa,' III. 121–128. 1913.

MASON, F. A. The Yeast-Fungi in Nature. 'The Naturalist for 1913,' 13–16. 1913.

MASSEE, GEORGE. Mycology, New and Old. 'The Naturalist for 1912,' 366–367. 1912.

MAWLEY, EDWARD. Report on Phenological Phenomena observed in Hertfordshire during the Year 1910. 'Trans. Herts N. H. S. F. C.' XIV. 291–297. 1912.

MEYRICK, E. Report of the Botanical Section. 'Report Marlb. Coll. N. H. Soc.' No. 60, 28–35. 1912.

NICHOLSON, CHARLES. The True Oxlip (*Primula elatior*) and its Allies. 'Selborne Mag.' XXIII. 149–154, 164–170. 1912.

PEEL, M. N. The Orchids of the Upper Hodder Valley. 'The Naturalist for 1913,' 29–32. 1913.

—— Aliens and Introduced Plants of the Upper Hodder. 'The Naturalist for 1913,' 141–143. 1913.

PRAEGER, R. LLOYD. Notes on the Flora of the Blaskets. 'Irish Naturalist,' XXI. 157–163. 1912.

PRAIN, Sir DAVID. Presidential Address: Botanical By-paths. 'South-Eastern Naturalist for 1912,' 1–15. 1912.

RAMSBOTTOM, J. Some Notes on the History of the Classification of the Uredinales. 'Trans. British Mycological Soc.' IV. 77–105. 1913.

—— Recent published Results on the Cytology of Fungus Reproduction. 'Trans. British Mycological Soc.' IV. 127–164. 1913.

REA, CARLETON. *Glischroderma cinctum* Fckl. 'Trans. British Mycological Soc.' IV. 64–65. 1913.

—— New and Rare British Fungi. 'Trans. British Mycological Soc.' IV. 186–198. 1913.

RICHARDSON, NELSON M. Phenological Report on First Appearances of Birds, Insects, &c., and First Flowering of Plants in Dorset during 1911. 'Proc. Dorset N. H. A. F. C.' XXXIII. 232–242. 1912.

RIDDELSDELL, Rev. H. J. Report (No. 4) on the Progress made in connection with the Flora of Gloucestershire. 'Proc. Cotteswold Nat. Field Club,' XVII. 381–383. 1912; XVIII. 90. 1913.

ROBINSON, Miss MAUDE. Downland Flowers. 'Report Brighton and Hove Nat. Hist. and Phil. Soc.' 1911–12, 8–13. 1912.

SALISBURY, E. J. Botanical Observations in Hertfordshire during the Year 1910. 'Trans. Herts N. H. S. F. C.' XIV. 301–302. 1912.

SAXTON, W. T. The Leaf-spots of *Richardia albo-maculata*, Hook. 'Trans. Royal Soc. of S. Africa,' III. 135–138. 1913.

SCHARFF, Dr. R. F. The Relation of the present Plant Population of the British Isles to the Glacial Epoch. 'Irish Naturalist,' XXI. 105–111. 1912.

SCOTT-ELLIOT, G. F. Scotch Forestry: the Romance and Business Side of it. 'Trans. Dumfriesshire and Galloway N. H. A. Soc.' XXIV. 181–189. 1912.

SCULLY, REGINALD W. Some introduced Plants in Kerry. 'Irish Naturalist,' XXI. 214–217. 1912.

SHENSTONE, J. C. The Gardens of Warley Place, Brentwood, Essex. 'Essex Naturalist,' XVII. 40–60. 1912.

SHOOSMITH, W. B. Diatoms found in the Midsummer Meadow Bathing Place. 'Journal Northants N. H. Soc.' XVI. 243–246. 1912.

SMITH, A. LORRAIN. *Phæangella empetri* Boud. (in Litt.) and some forgotten Discomycetes. 'Trans. British Mycological Soc.' IV. 74–76. 1913.

—— and J. RAMSBOTTOM. New or Rare Microfungi. 'Trans. British Mycological Soc.' IV. 165–185. 1913.

STAINFORTH, T. A Humber Salt-Marsh. 'The Naturalist for 1912,' 225–226. 1912.

THOMAS, H. HAMSHAW. The Jurassic Plant Beds of Roseberry Topping. 'The Naturalist for 1913,' 198–200. 1913.

WADDELL, Rev. C. H. Some County Down Plants. 'Irish Naturalist,' XXI. 133–134. 1912.

WAGER, HAROLD. The Sexuality of Fungi. 'The Naturalist for 1912,' 328. 1912.

WAKEFIELD, E. M. Notes on British Species of Corticium. 'Trans. British Mycological Soc.' IV. 113–120. 1913.

WALTON, GEORGE C. The Flora of Folkestone and its Vicinity. 'South-Eastern Naturalist for 1912,' 16–23. 1912.

WATSON, W. The Mosses of Somerset. 'Proc. Somerset Arch. N. H. Soc.' LVIII. 114–164. 1913.

WATTAM, W. E. L. Buckton Marsh, East Yorks. 'The Naturalist for 1912,' 298–300. 1912.

WILSON, ALBERT. On Gathering, Growing, and Preparing Mosses for the Herbarium. 'The Naturalist for 1913,' 128–130. 1913.

WILSON, WM. On the Potato. 'Trans. Edinburgh F. N. Mic. Soc.' VI. 413–416. 1912.

WOOD, J. MEDLEY. Addendum to Revised List of the Flora of Natal. 'Trans. Royal Soc. of S. Africa,' III. 47–60. 1913.

WOODHEAD, Dr. T. W. Plant Associations of Flamborough Head. 'The Naturalist for 1912,' 219–223. 1912.

— Notes on the Botany of Cautley and Tebay. 'The Naturalist for 1912,' 278–281. 1912.

Section L.—EDUCATIONAL SCIENCE.

HARDWICK, Prof. F. W. (Midland Inst. Eng.). Presidential Address: Technical Education in Mining. 'Trans. Inst. Min. Eng.' XLIV. 425–437. 1913.

MACKINNON, Prof. JAMES. Scholasticism, and the Revival of Classic Culture in Opposition to it. 'Proc. Glasgow Royal Phil. Soc.' XLIII. 130–152. 1912.

RYAN, FREDERICK W. School Attendance in Ireland. 'Journal Stat. Soc. Ireland,' XII. 583–594. 1912.

Section M.—AGRICULTURE.

DUDGEON, Miss E. C. Electrical Treatment on Potato Crops, 1911. 'Trans. Dumfriesshire and Galloway N. H. A. Soc.' XXIV. 143–145. 1912.

HOLLINGWORTH, G. H. The Effect of Grass over the Roots of Young Fruit Trees. 'Proc. Cotteswold Nat. Field Club,' XVIII. 88. 1913.

NEWMAN, L. F. Soils and Agriculture of Norfolk. 'Trans. Norfolk and Norwich Nat. Soc.' IX. 349–393. 1912.

PRIESTLEY, Prof. J. W. The Application of Electricity to Agriculture. 'Trans. Dumfriesshire and Galloway N. H. A. Soc.' XXIV. 140–143. 1912.

OBITUARY.

BENSON, THOMAS WALTER. By W. J. Benson. 'Trans. Inst. Min. Eng.' XLV. 107–110. 1913.

BERKLEY, CUTHBERT. By R. W. Berkley. 'Trans. Inst. Min. Eng.' XLV. 111–112. 1913.

BORNET, Dr. EDOUARD. By Prof. R. J. Harvey Gibson. 'Proc. Liverpool Bot. Soc. 1910–11,' 54. 1912.

BOVEY, Dr. HENRY TAYLOR. 'Trans. Liverpool Eng. Soc.' XXXIII. 382. 1912.

BULLEN, Rev. ROBERT ASHINGTON. By Rev. T. R. R. S[tebbing]. 'South-Eastern Naturalist for 1912,' l.–li. 1912.

BURTON, F. M. By T. S[heppard]. 'The Naturalist for 1912,' 186–187. 1912.

CAPPER, SAMUEL JAMES. By F. N. P[ierce]. 'Proc. Lancashire and Cheshire Entom. Soc. 1912,' 18–22. 1912.

CULPIN, HENRY. By T. S[heppard]. 'The Naturalist for 1913,' 17–19. 1913.

DARWIN, Sir GEORGE HOWARD. By Alfred T. De Lury. 'Journal Royal Astr. Soc. of Canada,' VII. 114–119. 1913.

HOLT, ALFRED. 'Trans. Liverpool Eng. Soc.' XXXIII. 383–385. 1912.

PANKHURST, EDWARD ALLOWAY. 'Report Brighton and Hove Nat. Hist. and Phil. Soc. 1911–12,' 32–34. 1912.

POINCARÉ, JULES HENRI. By Alfred T. De Lury. 'Journal Royal Astr. Soc. of Canada,' VI. 309–321. 1912.

REYNOLDS, Dr. OSBORNE. 'Trans. Liverpool Eng. Soc.' XXXIII. 381. 1912.

THOMPSON, J. TATHAM. By Dr. D. R. Paterson. 'Trans. Cardiff Nat. Soc.' XLIV. 23. 1912.

WATSON, Dr. WILLIAM. By John Lindsay. 'Trans. Edinburgh F. N. Mic. Soc.' VI. 447–452. 1912.

TRANSACTIONS OF THE SECTIONS.

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Section A.—MATHEMATICAL AND PHYSICAL SCIENCE.

President of the Section.—H. F. Baker, Sc.D., F.R.S.

THURSDAY, SEPTEMBER 11.

The President delivered the following Address:

The Place of Pure Mathematics.

It is not a very usual thing for the opening Address of this Section to be entrusted to one whose main energies have been devoted to what is called Pure Mathematics; but I value the opportunity in order to try to explain what, as I conceive it, the justification of the Pure Mathematician is. You will understand that in saying this I am putting myself in a position which belongs to me as little by vocation as by achievement, since it was my duty through many years to give instruction in all the subjects usually regarded as Mathematical Physics, and it is still my duty to be concerned with students in these subjects. But my experience is that the Pure Mathematician is apt to be regarded by his friends as a trifler and a visionary, and the consciousness of this becomes in time a paralysing dead-weight. I think that view is founded on want of knowledge.

Of course, it must be admitted that the mathematician, as such, has no part in those public endeavours that arise from the position of our Empire in the world, nor in the efforts that must constantly be made for social adjustment at home. I wish to make this obvious remark. For surely the scientific man must give his time and his work in the faith of at least an intellectual harmony in things; and he must wish to know what to think of all that seems out of gear in the working of human relations. His own cup of contemplation is often golden; he marks that around him there is fierce fighting for cups that are earthen, and largely broken; and many there are that go thirsting. And, again, the mathematician is as sensitive as others to the marvel of each recurring springtime, when, year by year, our common mother seems to call us so loudly to consider how wonderful she is, and how dependent we are, and he is as curious as to the mysteries of the development of living things. He can draw inspiration for his own work, as he views the spectacle of a starry night, and sees

> How the floor of heaven
> Is thick inlaid with patines of bright gold.
> Each orb, the smallest, in his motion, sings,

but the song, once so full of dread, how much it owes to the highest refinements of his craft, from at least the time of the Greek devotion to the theory of conic sections; how much, that is, to the harmony that is in the human soul. Yet the mathematician bears to the natural observer something of the relation which the laboratory botanist has come to bear to the field naturalist. Moreover, he is shut off from inquiries which stir the public imagination; when he looks back the ages over the history of his own subject the confidence of his friends who study

heredity and teach eugenics arouses odd feelings in his mind; if he feels the fascination which comes of the importance of such inquiries, he is also prepared to hear that the subtlety of Nature grows with our knowledge of her. Doubtless, too, he wishes he had some participation in the discovery of the laws of wireless telegraphy, or had something to say in regard to the improvement of internal-combustion engines or the stability of aeroplanes; it is little compensation to remember, though the mathematical physicist is his most tormenting critic, what those of his friends who have the physical instinct used to say on the probable development of these things, however well he may recall it.

But it is not logical to believe that they who are called visionary because of their devotion to creatures of the imagination can be unmoved by these things. Nor is it at all just to assume that they are less conscious than others of the practical importance of them, or less anxious that they should be vigorously prosecuted.

Why is it, then, that their systematic study is given to other things, and not of necessity, and in the first instance, to the theory of any of these concrete phenomena? This is the question I try to answer. I can only give my own impression, and doubtless the validity of an answer varies as the accumulation of data, made by experimenters and observers, which remains unutilised at any time.

The reason, then, is very much the same as that which may lead a man to abstain from piecemeal indiscriminate charity in order to devote his attention and money to some well-thought-out scheme of reform which seems to have promise of real amelioration. One turns away from details and examples, because one thinks that there is promise of fundamental improvement of methods and principles. This is the *argumentum ad hominem*. But there is more than that. The improvement of general principles is arduous, and if undertaken only with a view to results may be illtimed and disappointing. But as soon as we consciously give ourselves to the study of universal methods for their own sake another phenomenon appears. The mind responds, the whole outlook is enlarged, infinite possibilities of intellectual comprehension, of mastery of the relations of things, hitherto unsuspected, begin to appear on the mental horizon. I am well enough aware of the retort to which such a statement is open. But, I say, interpret the fact as you will, our intellectual pleasure in life cometh not by might nor by power—arises, that is, most commonly, not of set purpose—but lies at the mercy of the response which the mind may make to the opportunities of its experience. When the response proves to be of permanent interest—and for how many centuries have mathematical questions been a fascination?—we do well to regard it. Let us compare another case which is, I think, essentially the same. It may be that early forms of what now is specifically called Art arose with a view to applications; I do not know. But no one will deny that Art, when once it has been conceived by us, is a worthy object of pursuit; we know by a long trial that we do wisely to yield ourselves to a love of beautiful things, and to the joy of making them. Well, Pure Mathematics, as such, *is* an Art, a creative Art. If its past triumphs of achievement fill us with wonder, its future scope for invention is exhaustless and open to all. It is also a Science. For the mind of man is one; to scale the peaks it spreads before the explorer is to open ever new prospects of possibility for the formulation of laws of Nature. Its resources have been tested by the experience of generations; to-day it lives and thrives and expands and wins the life-service of more workers than ever before.

This, at least, is what I wanted to say, and I have said it with the greatest brevity I could command. But may I dare attempt to carry you further? If this seems fanciful, what will you say to the setting in which I would wish to place this point of view? And yet I feel bound to try to indicate something more, which may be of wider appeal. I said a word at starting as to the relations of science to those many to whom the message of our advanced civilisation is the necessity, above all things, of getting bread. Leaving this aside, I would make another reference. In our time old outlooks have very greatly changed; old hopes, disregarded perhaps because undoubted, have very largely lost their sanction, and given place to earnest questionings. Can anyone who watches doubt that the courage to live is in some danger of being swallowed up in the anxiety to acquire? May it not be, then, that it is good for us to realise, and to

confess, that the pursuit of things that are beautiful, and the achievement of intellectual things that bring the joy of overcoming, is at least as demonstrably justifiable as the many other things that fill the lives of men? May it not be that a wider recognition of this would be of some general advantage at present? Is it not even possible that to bear witness to this is one of the uses of the scientific spirit? Moreover, though the pursuit of truth be a noble aim, is it so new a profession; are we so sure that the ardour to set down all the facts without extenuation is, unassisted, so continuing a purpose? May science itself not be wise to confess to what is its own sustaining force?

Such, ladies and gentlemen, in crude, imperfect phrase, is the *apologia*. If it does not differ much from that which workers in other ways would make, it does, at least, try to represent truly one point of view, and it seems to me specially applicable to the case of Pure Mathematics. But you may ask: What, then, is this subject? What can it be about if it is not primarily directed to the discussion of the laws of natural phenomena? What kind of things are they that can occupy alone the thoughts of a lifetime? I propose now to attempt to answer this, most inadequately, by a bare recital of some of the broader issues of present interest—though this has difficulties, because the nineteenth century was of unexampled fertility in results and suggestions, and I must be as little technical as possible.

Precision of Definitions.

First, in regard to two matters which illustrate how we are forced by physical problems into abstract inquiries. It is a constantly recurring need of science to reconsider the exact implication of the terms employed; and as numbers and functions are inevitable in all measurement, the precise meaning of number, of continuity, of infinity, of limit, and so on, are fundamental questions; those who will receive the evidence can easily convince themselves that these notions have many pitfalls. Such an imperishable monument as Euclid's theory of ratio is a familiar sign that this has always been felt. The last century has witnessed a vigorous inquiry into these matters, and many of the results brought forward appear to be new; nor is the interest of the matter by any means exhausted. I may cite, as intelligible to all, such a fact as the construction of a function which is continuous at all points of a range, yet possesses no definite differential coefficient at any point. Are we sure that human nature is the only continuous variable in the concrete world, assuming it be continuous, which can possess such a vacillating character? Or I may refer to the more elementary fact that all the rational fractions, infinite in number, which lie in any given range, can be enclosed in intervals whose aggregate length is arbitrarily small. Thus we could take out of our life all the moments at which we can say that our age is a certain number of years, and days, and fractions of a day, and still have appreciably as long to live; this would be true, however often, to whatever exactness, we named our age, provided we were quick enough in naming it. Though the recurrence of these inquiries is part of a wider consideration of functions of complex variables, it has been associated also with the theory of those series which Fourier used so boldly, and so wickedly, for the conduction of heat. Like all discoverers, he took much for granted. Precisely how much is the problem. This problem has led to the precision of what is meant by a function of real variables, to the question of the uniform convergence of an infinite series, as you may see in early papers of Stokes, to new formulation of the conditions of integration and of the properties of multiple integrals, and so on. And it remains still incompletely solved

Calculus of Variations.

Another case in which the suggestions of physics have caused grave disquiet to the mathematicians is the problem of the variation of a definite integral. No one is likely to underrate the grandeur of the aim of those who would deduce the whole physical history of the world from the single principle of least action. Everyone must be interested in the theorem that a potential function, with a given value at the boundary of a volume, is such as to render a certain integral, representing, say, the energy, a minimum. But in that proportion one desires to be sure that the logical processes employed are free from objection. And, alas!

to deal only with one of the earliest problems of the subject, though the finally sufficient conditions for a minimum of a simple integral seemed settled long ago, and could be applied, for example, to Newton's celebrated problem of the solid of least resistance, it has since been shown to be a general fact that such a problem cannot have any definite solution at all. And, although the principle of Thomson and Dirichlet, which relates to the potential problem referred to, was expounded by Gauss, and accepted by Riemann, and remains to-day in our standard treatise on Natural Philosophy, there can be no doubt that, in the form in which it was originally stated, it proves just nothing. Thus a new investigation has been necessary into the foundations of the principle. There is another problem, closely connected with this subject, to which I would allude: the stability of the solar system. For those who can make pronouncements in regard to this I have a feeling of envy; for their methods, as yet, I have a quite other feeling. The interest of this problem alone is sufficient to justify the craving of the Pure Mathematician for powerful methods and unexceptionable rigour.

Non-Euclidian Geometry.

But I turn to another matter. It is an old view, I suppose, that geometry deals with facts about which there can be no two opinions. You are familiar with the axiom that, given a straight line and a point, one and only one straight line can be drawn through the point parallel to the given straight line. According to the old view the natural man would say that this is either true or false. And, indeed, many and long were the attempts made to justify it. At length there came a step which to many probably will still seem unintelligible. A system of geometry was built up in which it is assumed that, given a straight line and a point, an infinite number of straight lines can be drawn through the point, in the plane of the given line, *no one* of which meets the given line. Can there then, one asks at first, be two systems of geometry, both of which are true, though they differ in such an important particular? Almost as soon believe that there can be two systems of Laws of Nature, essentially differing in character, both reducing the phenomena we observe to order and system—a monstrous heresy, of course! I will only say that, after a century of discussion we are quite sure that many systems of geometry are possible, and true; though not all may be expedient. And if you reply that a geometry is useful for life only in proportion as it fits the properties of concrete things, I will answer, first, are the heavens not then concrete? And have we as yet any geometry that enables us to form a consistent logical idea of furthermost space? And, second, that the justification of such speculations is the interest they evoke, and that the investigations already undertaken have yielded results of the most surprising interest.

The Theory of Groups.

To-day we characterise a geometry by the help of another general notion, also, for the most part, elaborated in the last hundred years, by means of its group. A group is a set of operations which is closed, in the same sense that the performance of any two of these operations in succession is equivalent to another operation of the set, just as the result of two successive movements of a rigid body can be achieved by a single movement. One of the earliest conscious applications of the notion was in the problem of solving algebraic equations by means of equations of lower order. An equation of the fourth order can be solved by means of a cubic equation, because there exists a rational function of the four roots which takes only three values when the roots are exchanged in all possible ways. Following out this suggestion for an equation of any order, we are led to consider, taking any particular rational function of its roots, what is the group of interchanges among them which leaves this function unaltered in value. This group characterises the function, all other rational functions unaltered by the same group of interchanges being expressible rationally in terms of this function. On these lines a complete theory of equations which are soluble algebraically can be given. Anyone who wishes to form some idea of the richness of the landscape offered by Pure Mathematics might do worse than make himself acquainted with this comparatively small district of it. But the theory of groups has other applications. It may be interesting to refer to the

circumstance that the group of interchanges among four quantities which leave unaltered the product of their six differences is exactly similar to the group of rotations of a regular tetrahedron whose centre is fixed, when its corners are interchanged among themselves. Then I mention the historical fact that the problem of ascertaining when that well-known linear differential equation called the hypergeometric equation has all its solutions expressible in finite terms as algebraic functions, was first solved in connection with a group of similar kind. For any linear differential equation it is of primary importance to consider the group of interchanges of its solutions when the independent variable, starting from an arbitrary point, makes all possible excursions, returning to its initial value. And it is in connection with this consideration that one justification arises for the view that the equation can be solved by expressing both the independent and dependent variables as single-valued functions of another variable. There is, however, a theory of groups different from those so far referred to, in which the variables can change continuously; this alone is most extensive, as may be judged from one of its lesser applications, the familiar theory of the invariants of quantics. Moreover, perhaps the most masterly of the analytical discussions of the theory of geometry has been carried through as a particular application of the theory of such groups.

The Theory of Algebraic Functions.

If the theory of groups illustrates how a unifying plan works in mathematics beneath bewildering detail, the next matter I refer to well shows what a wealth, what a grandeur, of thought may spring from what seem slight beginnings. Our ordinary integral calculus is well-nigh powerless when the result of integration is not expressible by algebraic or logarithmic functions. The attempt to extend the possibilities of integration to the case when the function to be integrated involves the square root of a polynomial of the fourth order, led first, after many efforts, among which Legendre's devotion of forty years was part, to the theory of doubly-periodic functions. To-day this is much simpler than ordinary trigonometry, and, even apart from its applications, it is quite incredible that it should ever again pass from being among the treasures of civilised man. Then, at first in uncouth form, but now clothed with delicate beauty, came the theory of general algebraical integrals, of which the influence is spread far and wide; and with it all that is systematic in the theory of plane curves, and all that is associated with the conception of a Riemann surface. After this came the theory of multiply-periodic functions of any number of variables, which, though still very far indeed from being complete, has, I have always felt, a majesty of conception which is unique. Quite recently the ideas evolved in the previous history have prompted a vast general theory of the classification of algebraical surfaces according to their essential properties, which is opening endless new vistas of thought.

Theory of Functions of Complex Variables: Differential Equations.

But the theory has also been prolific in general principles for functions of complex variables. Of greater theories, the problem of automorphic functions alone is a vast continent still largely undeveloped, and there is the incidental problem of the possibilities of geometry of position in any number of dimensions, so important in so many ways. But, in fact, a large proportion of the more familiar general principles, taught to-day as theory of functions, have been elaborated under the stimulus of the foregoing theory. Besides this, however, all that precision of logical statement of which I spoke at the beginning is of paramount necessity here. What exactly is meant by a curve of integration, what character can the limiting points of a region of existence of a function possess, how even best to define a function of a complex variable, these are but some obvious cases of difficulties which are very real and pressing to-day. And then there are the problems of the theory of differential equations. About these I am at a loss what to say. We give a name to the subject, as if it were one subject, and I deal with it in the fewest words. But our whole physical outlook is based on the belief that the problems of Nature are expressible by differential equations; and our knowledge of even the possibilities of the solutions

of differential equations consists largely, save for some special types, of that kind of ignorance which, in the nature of the case, can form no idea of its own extent. There are subjects whose whole content is an excuse for a desired solution of a differential equation; there are infinitely laborious methods of arithmetical computation held in high repute of which the same must be said. And yet I stand here to-day to plead with you for tolerance of those who feel that the prosecution of the theoretic studies, which alone can alter this, is a justifiable aim in life! Our hope and belief is that over this vast domain of differential equations the theory of functions shall one day rule, as already it largely does, for example, over linear differential equations.

Theory of Numbers.

In concluding this table of contents, I would also refer, with becoming brevity, to the modern developments of theory of numbers. Wonderful is the fascination and the difficulty of these familiar objects of thought—ordinary numbers. We know how the great Gauss, whose lynx eye was laboriously turned upon all the physical science of his time, has left it on record that in order to settle the law of a plus or minus sign in one of the formulæ of his theory of numbers he took up the pen every week for four years. In these islands perhaps our imperial necessities forbid the hope of much development of such a theoretical subject. But in the land of Kummer and Gauss and Dirichlet the subject to-day claims the allegiance of many eager minds. And we can reflect that one of the latest triumphs has been with a problem known by the name of our English senior wrangler, Waring—the problem of the representation of a number by sums of powers.

Ladies and gentlemen, I have touched only a few of the matters with which Pure Mathematics is concerned. Each of those I have named is large enough for one man's thought; but they are interwoven and interlaced in indissoluble fashion and form one mighty whole, so that to be ignorant of one is to be weaker in all. I am not concerned to depreciate other pursuits, which seem at first sight more practical; I wish only, indeed, as we all do, it were possible for one man to cover the whole field of scientific research; and I vigorously resent the suggestion that those who follow these studies are less careful than others of the urgent needs of our national life. But Pure Mathematics is not the rival, even less is it the handmaid, of other branches of science. Properly pursued, it is the essence and soul of them all. It is not for them; they are for it; and its results are for all time. No man who has felt its fascination can be content to be ignorant of any manifestation of regularity and law, or can fail to be stirred by all the need of adjustment of our actual world.

And if life is short, if the greatest magician, joining with the practical man, reminds us that, like this vision,

> The cloud-capp'd towers, the gorgeous palaces,
> The solemn temples, the great globe itself,
> Yea, all which it inherit, shall dissolve
> And . . . . leave not a rack behind,

we must still believe that it is best for us to try to reach the brightest light. And all here must believe it; for else—no fact is more firmly established—we shall not study science to any purpose.

But that is not all I want to say, or at least to indicate. I have dealt so far only with proximate motives; to me it seems demonstrable that a physical science that is conscientious requires the cultivation of Pure Mathematics; and the most mundane of reasons seem to me to prompt the recognition of the æsthetic outlook as a practical necessity, not merely a luxury, in a successful society. Nor do I want to take a transcendental ground. Every schoolboy, I suppose, knows the story of the child born so small, if I remember aright, that he could be put into a quart pot, in a farmhouse on the borders of Lincolnshire—it was the merest everyday chance. By the most incalculable of luck his brain-stuff was so arranged, his parts so proportionately tempered, that he became Newton, and taught us the laws of the planets. It was the blindest concurrence of physical circumstances; and so is all our life. Matter in certain relations to itself,

working by laws we can examine in the chemical laboratory, produces all these effects, produces even that state of brain which accompanies the desire to speak of the wonder of it all. And the same laws will inevitably hurl all into confusion and darkness again; and where will all our joys and fears, and all our scientific satisfaction, be then?

As students of Science, we have no right to shrink from this point of view; we are pledged to set aside prepossession and dogma, and examine what seems possible, wherever it may lead. Even life itself may be mechanical, even the greatest of all things, even personality, may some day be resoluble into the properties of dead matter, whatever that is. We can all see that its coherence rises and falls with illness and health, with age and physical conditions. Nor, as it seems to me, can anything but confusion of thought arise from attempts to people our material world with those who have ceased to be material.

An argument could perhaps be based on the divergence, as the mathematician would say, of our comprehension of the properties of matter. For though we seem able to summarise our past experiences with ever-increasing approximation by means of fixed laws, our consciousness of ignorance of the future is only increased thereby. Do we feel more, or *less*, competent to grasp the future possibilities of things, when we can send a wireless message 4,000 miles, from Hanover to New Jersey?

Our life is begirt with wonder, and with terror. Reduce it by all means to ruthless mechanism, *if you can*; it will be a great achievement. But it can make no sort of difference to the fact that the things for which we live are spiritual. The rose is no less sweet because its sweetness is conditioned by the food we supply to its roots. It is an obvious fact, and I ought to apologise for remarking it, were it not that so much of our popular science is understood by the hasty to imply an opposite conclusion. If a chemical analysis of the constituents of sea water could take away from the glory of a mighty wave breaking in the sunlight, it would still be true that it was the mind of the chemist which delighted in finding the analysis. Whatever be its history, whatever its physical correlations, it is an undeniable fact that the mind of man has been evolved; I believe that is the scientific word. You may speak of a continuous upholding of our material framework from without; you may ascribe fixed qualities to something you call matter; or you may refuse to be drawn into any statement. But anyway, the fact remains that the precious things of life are those we call the treasures of the mind Dogmas and philosophies, it would seem, rise and fall. But gradually accumulating throughout the ages, from the earliest dawn of history, there is a body of doctrine, a reasoned insight into the relations of exact ideas, painfully won and often tested. And this remains the main heritage of man; his little beacon of light amidst the solitudes and darknesses of infinite space; or, if you prefer, like the shout of children at play together in the cultivated valleys, which continues from generation to generation.

Yes, and continues for ever! A universe which has the potentiality of becoming thus conscious of itself is not without something of which that which we call memory is but an image Somewhere, somehow, in ways we dream not of, when you and I have merged again into the illimitable whole, when all that is material has ceased, the faculty in which we now have some share, shall surely endure; the conceptions we now dimly struggle to grasp, the joy we have in the effort, these are but part of a greater whole. Some may fear, and some may hope, that they and theirs shall not endure for ever. But he must have studied Nature in vain who does not see that our spiritual activities are inherent in the mighty process of which we are part; who can doubt of their persistence.

And, on the intellectual side, of all that is best ascertained, and surest, and most definite, of these; of all that is oldest and most universal; of all that is most fundamental and far-reaching, of these activities, Pure Mathematics is the symbol and the sum.

The following Papers were then read:

1. *The Nature of X-Rays. By* Professor C. G. Barkla, *F.R.S.*

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2. *The Structure of the Atom.*
By Professor Sir J. J. Thomson, *F.R.S.*

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3. *The Relation between Entropy and Probability.*
By Professor H. A. Lorentz.

The important problem of the interpretation of entropy in the terms of molecular theory may be considered as having been solved by the physicists who developed the methods of modern statistical mechanics. It is now universally recognised that the entropy of a body in a certain state is intimately connected with the probability of that state, the relation between the two being expressd by Boltzmann's formula

$$S = \frac{R}{N} \log P,$$

where S is the entropy, P the probability, R the gas constant for a gramme-molecule and N the number of molecules in a gramme-molecule.

The question is, however, in what way the probability is to be evaluated.

In order to find P, and consequently S, as a definite function of the energy E and appropriate geometrical parameters, such as the volume v in the case of a gas or a liquid, one may proceed as follows. Let $q_1, q_2 \ldots q_s$ be the co-ordinates which determine the position of the particles of the body, $p_1, p_2 \ldots p_s$ the corresponding momenta. Conceive a polydimensional space (the 'extension in phase') in which the 2 S quantities $q_1 \ldots p_s$ are taken as co-ordinates, so that the state of the body is represented by a single point. Consider further two surfaces in the space $(q_1, \ldots p_s)$, the first of which is characterised by the condition that at each of its points the energy has a definite value E, whereas the second corresponds in the same way to the value E + dE. Then the volume of the layer between these surfaces will be proportional to dE and may therefore be represented by PdE, the factor P being a function of E and also of the volume v, the value of which is to be taken into account in the calculation. Now, if the quantity P, defined in this way, is substituted in Boltzmann's formula, S becomes identical with the thermodynamical entropy. In the case of a mono-atomic gas, this may be shown by direct calculation and the proposition may be extended to other bodies by means of a mode of reasoning (based on a certain assumption) which cannot now be considered.

The above method is closely connected with Gibbs's microcanonical ensembles, and it is to be remarked that the introduction of canonical ensembles likewise enables us to determine a thermodynamical function. As is well known, an ensemble of the latter kind consists of a very great number of systems or bodies, whose representative points are distributed throughout the extension in phase with a density given by the expression

$$Ae^{\frac{\Psi - E}{\Theta}}$$

where A is the total number of systems, Θ a constant that plays the part of the temperature, and Ψ another constant that proves to be the 'free energy.' Now, if $d\Omega$ is an element of the extension in phase, we have

$$\int e^{\frac{\Psi - E}{\Theta}} d\Omega = 1$$

(because the integral of $Ae^{\frac{\Psi - E}{\Theta}} d\Omega$ must give the total number of systems) or

$$e^{-\frac{\Psi}{\Theta}} = \int e^{-\frac{E}{\Theta}} d\Omega.$$

By this equation one can calculate the free energy for a given temperature and a given value of the volume. The result will be connected with the value of the entropy deduced from Boltzmann's formula, in the way that is known from thermodynamics.

On account of the enormous number of molecules contained in a body, Boltzmann's formula has a very remarkable property, namely that great changes in the value assigned to the probability P have no appreciable influence on the entropy S.

Consider, for instance, the case of a mono-atomic gas. If the number of its molecules is n, one finds

$$P = C v^n E^{\frac{3n}{2} - 1}$$

C being a determinate constant factor. Hence, if we omit the corresponding term in the entropy,

$$S = n \frac{R}{N} \log \left(v E^{\frac{3}{2} - \frac{1}{n}}\right),$$

for which we may write, since n is a very great number,

$$S = n \frac{R}{N} \log \left(v E^{\frac{3}{2}}\right),$$

an expression which will lead to a number that is neither very small nor very great, when the mass considered is comparable with a gramme-molecule.

Now, if the value of P is multiplied by the number of molecules n, or even by a high power of this number, such as n^{100}, this does not produce any appreciable difference in the value of S. Indeed, S is increased in these cases by $\frac{R}{N} \log n$, or $100 \frac{R}{N} \log n$, and this is very small in comparison with the above value, because for large numbers the logarithm is very much smaller than the number itself. Boltzmann's formula is therefore wholly insensible to such factors as n or n^{100} in the value of the probability.

The way in which, in the case of a gas, P depends on the volume v, may be understood by a very simple reasoning. If the n molecules are distributed at random over a volume v, the probability that they shall all lie in one half of it is $P' = \frac{1}{2^n}$, whereas $P = 1$ if all possible distributions are taken together. The difference between the two values is enormous. Yet the corresponding difference in the entropy is no more than $n \frac{R}{N} \log 2$, an expression really corresponding to the change in the entropy when the volume is reduced to half its original value.

In virtue of the property of Boltzmann's formula here pointed out, one is free to a great extent in the choice of the value of P. The probability, for instance, that exactly $\frac{n}{2}$ molecules lie in one half of the volume v and the remaining ones in the other half—which is the most probable distribution—is given by

$$P'' = \frac{1}{2^n} \frac{n!}{\left(\frac{n}{2}!\right)^2},$$

or, with a sufficient approximation

$$P'' = \sqrt{\frac{2}{n}}.$$

This is much smaller than unity, showing that the exact realisation of the most probable distribution is very improbable. Yet it does not make any difference worth considering in the value of S, whether this small value or the value 1 is substituted in the formula. This exemplifies that, in order to determine the value of the entropy, one may as well take for P the probability of the most probable state of things, as the much higher value that is obtained if all possible states are included.

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4. *The Structure of the Atom. By* Professor E. RUTHERFORD, *F.R.S.*

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5. *The Electrical Resistance of Thin Metallic Films. By* W. F. G. SWANN, *A.R.C.S., D.Sc.*

If the specific resistance of a film is plotted against its time of deposit, the curve shows, as is well known, a sharp bend. The theory usually given

to account for this phenomenon results in the bend occurring at a thickness comparable with the mean free path. If the mean free path varies as rapidly with the temperature as is required by the usual considerations drawn from the Thomson effect, then, if we plot the specific resistance against the time of deposit for the same set of films at ordinary temperatures and at liquid-air temperature the bend should occur for entirely different times of deposit in the two cases.

A set of platinum films was deposited on glass in the same vacuum. The resistances of the films were measured at 100°C., 14°C., and –180°C., and no appreciable alteration in the position of the bend was found. As in the experiments of Longden, it was found that the thick films showed a positive temperature coefficient and the thin films a negative temperature coefficient. The negative temperature coefficient for the very thin films was very large, and, moreover, two films were obtained which showed a decrease in resistance on heating from –180°C. to 14°C., and an increase on heating from 14°C. to 100° C. The explanation of these facts is not contained in the theory referred to above, and a new theory is put forward, in which it is supposed that the molecules come down in groups which become more intimately packed as the time of deposit increases. Only those electrons which have sufficiently high velocities to enable them to escape from one group to an adjacent group are able to take part in the conduction between the groups. The formula developed for this case gives for the specific resistance S the value

$$S = \sqrt{\frac{3\pi}{2}}\,\frac{a\theta}{ne^2\lambda v}\left\{1 + \frac{4}{3}\frac{\lambda}{l}\,\mathrm{F}(a)\right\}$$

where λ is the mean free path, l is the average distance across a group, a^2 is written for $\frac{3mu^2}{4a\theta}$ (u being the velocity which an electron must have perpendicular to the boundary of a group in order to escape to the next group), and $\mathrm{F}(a)$ is written for

$$\epsilon^{a^2} - (1 + a^2) + 2a^3\epsilon^{a^2}\int_a^{\infty} \epsilon^{-x^2}\,dx$$

The other symbols have the usual significance, ϵ being the base of the Napierian system of logarithms. This formula contains the explanation of all the above phenomena found experimentally. A more complete formula is also developed, showing variations from Ohm's law which may become appreciable in the films under certain conditions

FRIDAY, SEPTEMBER 12.

Discussion on Radiation.

Mr. J. H. Jeans: Any discussion of the nature of radiation is of necessity inextricably involved in the larger question as to the ultimate form of the laws which govern the smallest processes of nature. These laws have so far been believed to be expressible in the form of differential equations, a form implying continuity and infinite divisibility of time and space. It now appears that these laws must undergo a very extensive revision.

The problem is seen in its most crucial form in connection with black-body radiation. Chronologically the black-body problem was the first by which attention was drawn to the wider problem; logically, the difficulties of the wider problem are most readily focussed by fixing our attention on the simpler and more definite problems associated with black-body radiation.

Consider a finite volume of any continuous and homogeneous medium—for simplicity, say, a cube of unit volume. Through this medium waves of different wave-lengths can be transmitted, and certain wave-lengths will correspond to natural free vibrations of the unit volume of the medium. It is merely a matter of geometry to count these vibrations and classify them according to their wave-length. In the 'spectrum' of wave-lengths so obtained the 'lines' will be very

close together, as soon as we come to wave-lengths short in comparison with the dimensions of the medium under consideration. It is readily shown that the number of independent free-vibrations having wave-lengths within the small range between λ and $\lambda + d\lambda$ is

$4\pi\lambda^{-4}d\lambda$ when the medium is a gas transmitting sound-waves,
$8\pi\lambda^{-4}d\lambda$ „ „ free ether transmitting light-waves,
$12\pi\lambda^{-4}d\lambda$ „ „ a solid „ elastic-waves.

Suppose that, when the medium is in thermodynamical equilibrium at temperature T, the partition of energy in the medium according to wave-length can be in some way observed or determined. Then, obviously, we can deduce the average energy of vibrations of every wave-length.

For instance, let us examine the non-controversial case of a gas. We may assume that the molecules move with velocities determined by the well-known law of Maxwell. This random motion of the molecules can be resolved, by ordinary Fourier analysis, into the motion of regular trains of waves, so that the heat energy of the gas is resolved into the energy of regular sound-waves or vibrations. The resulting partition of energy is found to be such that the energy per unit volume of wave-length between λ and $\lambda + d\lambda$ is $4\pi \mathrm{RT}\lambda^{-4}d\lambda$, where R is the gas constant and T the temperature (abs.). Since the number of independent vibrations within this range is $4\pi\lambda^{-4}d\lambda$, it follows that the average energy of each vibration is RT.

In the case of light waves in the ether, the determination of the partition of energy according to wave-length is a subject for direct experimental investigation. The experiments of Lummer and Pringsheim show that the partition of energy is given with great (and probably perfect) accuracy by the well known formula of Planck,

$$8\pi \mathrm{RT}\lambda^{-4}d\lambda \times \frac{x}{e^x - 1}, \text{ where } x = \frac{h\nu}{\mathrm{RT}}, \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

in which h is Planck's universal constant, and ν is the number of vibrations per unit time. Knowing that the number of vibrations within the range $d\lambda$ of wavelength is $8\pi\lambda^{-4}d\lambda$, it follows that the average energy of each vibration of wave length λ must be

$$\mathrm{RT} \times \frac{x}{e^x - 1} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

There is no direct means of determining the partition of heat-energy in a solid, but the work of Debye has provided a very convincing, although indirect solution, to the problem. The total heat energy of a solid can, of course, be obtained from a knowledge of the specific heats at all temperatures. Debye has shown that all experimental determinations of the specific heat—extending over a great range of temperature and a wide variety of substances—are exactly satisfied by assuming that the total heat-energy of a substance per unit volume is $\Sigma\,\mathrm{RT} \times \frac{x}{e^x - 1}$, where the summation extends exactly over all the independent free vibrations of the solid, the number of these within a range of wavelength $d\lambda$ being $12\pi\lambda^{-4}d\lambda$. In other words, Debye shows that the heat-energy of a solid, and its variations with temperature, are exactly accounted for by assigning a mean energy

$$\mathrm{RT} \times \frac{x}{e^x - 1} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

to each elastic vibration of the solid. The explanation is so simple, and its agreement with experiment so complete, that few will venture to doubt its truth. Thanks to the work of Debye, we may say, with more confidence than is possible in most problems of modern physics, that we know the truth and the whole truth about the partition of the heat-energy in a solid; the heat-energy is simply the sum of the contributions of the different elastic solid waves, each having average energy given by formula (3), while the contributions from the motions of free electrons and all other sources are negligible.

We accordingly see that the average energy of a vibration in a gas is RT, while that in ether or a solid is RT $\times \frac{x}{\epsilon^x - 1}$. It will, of course, be remarked that the latter formula reduces to the former on putting $x=0$. It may further be noticed that the values of ν involved in the gas problem are very small, compared with those involved in the other problems, so small, in fact, that x is negligible, and the formula (3) becomes indistinguishable from RT.

Knowing the average energy of each vibration in a medium, it may or may not be possible to deduce some information as to the mechanism by which this partition of energy is produced. In the special case in which the partition of energy is such that each vibration has energy RT $\times \frac{x}{\epsilon^x - 1}$, the problem has been solved with great completeness by Poincaré. The quite definite result is obtained that, to arrive at this particular law of partition of energy, the exchange of energy between matter and ether must take place by finite jumps of amount ϵ, given by $\epsilon = h\nu$. This is, of course, the hypothesis, spoken of briefly as the quantum-hypothesis, which was first suggested by Planck, and from which his radiation formula (1) was first deduced. It now appears from the work of Poincaré that no other hypothesis could have led to Planck's formula; thus *the result of experiment leads inevitably to the law* RT $\times \frac{x}{\epsilon^x - 1}$, *and this in turn leads inevitably to the quantum-hypothesis.*

This result is so complete, so definite, and above all so revolutionary, that it will naturally be most closely scrutinised. We shall probably feel inclined to trust to the accuracy of Poincaré's mathematics, and examine the physical assumptions on which the result is based. They are two in number. First is the assumption that the average energy of a vibration in matter is the same as that in ether—in other words, the assumption that formulæ (2) and (3) are identical. Poincaré based this assumption on a theoretical proof by Planck, but since he wrote the more direct evidence of Debye's work has appeared, and may be considered to have put the matter beyond doubt. Next comes the assumption that formulæ (2) and (3) represent a real final state of thermodynamical equilibrium, and this assumption is perhaps slightly more open to question. Speaking for myself, I may perhaps be allowed to say that I have devoted several years of work to an attempt, quite unfruitful as it turned out, to reconcile the laws of radiation with the classical mechanics by assuming that formulæ (1), (2), and (3) do *not* represent a real final state. The more one works on this assumption the more one is forced to realise that all the facts are against it; the classical mechanics, coupled as they must be with this assumption, really show no power of explaining the facts of radiation; the new mechanics, based on the quantum hypothesis, show just that power of explaining and predicting facts which is to be expected of a new truth in its infancy.

Some of the more conservative of us may feel tempted to challenge the accuracy of the law (2, 3) on which Poincaré's result is based, but this possibility has been foreseen by Poincaré. He proves, in his own words,[1]

'L'hypothèse des quanta est la seule qui conduise à la loi de Planck.'

'Quelle que soit la loi du rayonnement, si l'on suppose que le rayonnement total est fini, on sera conduit à une fonction présentant des discontinuités analogues à celles que donne l'hypothèse des quanta.'

There is no escape, then, by appealing to errors of observation; a discontinuous system of mechanics is in any case thrust upon us, and all that an appeal to errors of observation could possibly do would be to modify slightly the laws governing the system of discontinuities.

One special importance of Poincaré's result is that it divides all possible views and theories of radiation into two sharp classes. Every view or theory must logically involve either the belief that Poincaré is wrong, or the belief that he is right, *together with all that this involves.* His work has shown that there is no middle way. For myself I feel logically compelled to accept the quantum-hypothesis in its entirety.

But logical necessity of this kind is made mentally more palatable if we can

[1] *Journ. de Phys.*, January 1912, pp. 37, 39.

discover direct evidence, or phenomena other than those from which it is derived, to bear witness to its truth. First among such phenomena stands the photo-electric effect. When light of high frequency falls on a clean metallic surface electrons are shot off with a measurable velocity. This velocity is found to depend not on the intensity of the light, but on its frequency, being given by $\frac{1}{2}mv^2 = h\nu - c$. Here c varies from metal to metal, and is found to be equal to the work required to set free one electron from an atom of the metal in question. Thus the total energy yielded up by the radiation to the matter is exactly h. It is very significant that if the incident light is of frequency so low that $h\nu < c$, no electrons are emitted, no matter how intense the light, whereas even the feeblest light of a frequency greater than c/h will at once discharge electrons.

Here we have a phenomenon totally unlike anything which can be explained by the classical mechanics, and one which gives, I think, as direct and as convincing evidence as we can reasonably ask for, of the truth of the quantum theory.

In this phenomenon, because the transfer of energy is from ether to matter, the value of ϵ is determined from the frequency ν. When the transfer is in the other direction the value of ν must be determined from ϵ. The energy may arrange itself as required, for instance, by the conservation of energy, any energy not required by the matter being shot off as radiation, and the frequency of the emitted light being determined by the amount of energy available $h\nu = \epsilon$. Thus, the wave-length of Rontgen rays may be determined by the energy of impact, and a dissipation of energy as light passes through matter may result in a lowering of the frequency of the light (fluorescence). By following this principle implicitly Dr. Bohr has arrived at a most ingenious and suggestive, and I think we must add convincing, explanation of the laws of spectral series.

Dr. Bohr assumes that the atom is formed on the model of electron-satellites revolving round a positive nucleus as primary. According to the classical mechanics, a vast number of orbits forming a doubly infinite continuous series would have been possible for each electron. Dr. Bohr assumes that under the new mechanics only certain of these orbits are possible—the doubly infinite continuous series is reduced to a singly infinite discontinuous series by adding to the restrictions required by the old mechanics the additional restrictions (i.) that the orbits must be circular, (ii.) that the angular momentum of each electron must be a multiple of $h/2\pi$ where h is Planck's constant. The only justification at present put forward for these assumptions is the very weighty one of success.

A brief illustration of the type of result obtained will be given by the consideration of a single electron of charge e revolving round a nucleus of charge $+E$. When $E = e$ we obtain Dr. Bohr's conception of the neutral hydrogen atom; when $E = 2e$ we obtain the positively charged helium atom. The orbit may be any one of the circular orbits possible under the old mechanics, provided that the angular momentum is an integral multiple of $h/2\pi$, say $\tau h/2\pi$. It is easily found that the energy of such orbits must be of the form

$$-W = \frac{2\pi^2 me^2E^2}{\tau^2h^2}$$

(where $\tau = 1, 2, 3, \ldots$), the corresponding radius a is given by $a = \frac{\tau^2h^2}{2\pi^2meE}$, and the angular velocity by $\omega = \frac{4\pi^2me^2E^2}{\tau^3h^3}$. The most stable configuration ($-W$ a maximum) is that for which $\tau = 1$; this will give the normal hydrogen atom; on putting $\tau = 1$ and substituting numerical values, it is found that W, a and ω have just about the right values. The passage from a less stable to a more stable state (say, τ_1 to τ_2) is supposed to be accompanied by an emission of radiation of energy equal to the difference between the energy of the two states. Assuming the frequency of this radiation to be determined by the amount of energy available ($h\nu = \epsilon$), the formula obtained for ν is

$$\nu = R\left(\frac{1}{\tau_2^2} - \frac{1}{\tau_1^2}\right)$$

where R stands for $\frac{2\pi^2 me^2 E^2}{h^3}$. Dr. Bohr shows how this formula includes the

well known Balmer's series, the Paschen infra-red series, the Pickering (ζ Puppis) series, and the series recently discovered by Fowler. There is remarkably close numerical agreement between the calculated value of the constant R (Rydberg's constant) and its observed value.

The series of results obtained in this way are, I think, far too striking to be dismissed merely as accidental. At the same time, it would be futile to deny that there are difficulties, still unsurmounted, which appear to be enormous. I would mention in particular the difficulties of explaining the Zeeman effect and interference.

The consideration of this last difficulty introduces us to a wider problem—namely, the difficulty of reconciling the hypothesis of the quantum theory with the established facts of the undulatory theory of light. It is hardly too much to say that the two theories appear to be in active antagonism wherever they come in contact. Everywhere the undulatory theories demand that radiation should be capable of spreading and dividing indefinitely; while the quantum theory demands the reverse, at least when there is interaction between matter and ether. The conflict is, perhaps, shown at its keenest in the case of X-rays. These can be reflected and diffracted as though they were subject to the spreading and division required by the undulatory theory, while the same rays have the capacity of ionisation at a distance of, perhaps, 100 yards, exactly as though their energy were atomic and concentrated in the way demanded by the quantum theory. The conflict of the two sets of views appears so definitely and so acutely in this case that it may, perhaps, be hoped that the resolution of the difficulty here may go a long way towards solving the wider general problem.

Another problem of a more abstract nature which exhibits the conflict of the two theories is the following: Consider a very few electrons shut up in a radiation-free and perfectly reflecting enclosure, left to move freely. According to the classical laws (or any system of continuous laws) the electrons will set up an electro-magnetic field, and the energy of this field must ultimately be distributed according to the law of equi-partition $8\pi \mathrm{RT} \lambda^{-4} d\lambda$. Would this really happen? If not, at what exact point do the classical laws break down? If it does happen, is the resulting energy in the ether identical with ordinary light, or is it something quite different? If it is the same, how does it happen that radiation in thermodynamical equilibrium at temperature T can obey the law $8\pi \mathrm{RT} \lambda^{-4} d\lambda$, and can also obey Planck's law?

The boldest and simplest attempt at reconciliation between the conflicting theories lies in abandoning the ether altogether, and relying on some purely descriptive principle, such as that of relativity. There is probably no adequate reason why the ultimate interpretation of the universe should be expected to be dynamical rather than kinetic and descriptive. On the other hand, it is doubtful whether this very drastic remedy does more than merely shift the difficulty from one point to another; if there were no ether Debye's interpretation of heat-energy would demand quanta of material energy, each one indivisible, and yet spread over a finite region of space.

Any attempt at a dynamical interpretation demands a consideration of the meaning of h. The following vague suggestion is put forward very tentatively.

The value of h is given by

$$\frac{h}{2\pi} = c\,\frac{(4\pi e)^2}{\mathrm{V}}.$$

where c is a numerical constant, of which the value is very nearly, or perhaps exactly, equal to unity. Is, then, the new unit h anything more than a reappearance of the old unit $(4\pi e)$? Is the apparent atomicity of action or energy or angular momentum anything more than the atomicity of electricity? For consider what is meant by the fact that e is constant throughout the universe. We are probably no longer content to regard the electrons as 'manufactured articles,' all originally made similar. It is more rational to suppose the electrons to be formed out of some pervading medium, and to be all similar because the properties of this medium require that they should be all similar. If we definitely suppose this medium to be the ether, then the Maxwell equations cannot be the full and complete equations of the ether, for they do not imply the constancy of e. We must imagine the full equations to involve e (or h) as well as the

Maxwell terms. These equations must be of an atomic or discontinuous nature (*e.g.* they may be equations of finite differences instead of differential equations), both in order to satisfy the condition of Poincaré mentioned above, and to account for the atomicity of e. These equations will form the basis of the new dynamics. If in forming the equation of wave-propagation the new terms happen to be eliminated out, then the equation $\nabla^2 \phi = a^2 \frac{d^2\phi}{dt^2}$ will be true in the new dynamics as in the old, and there will be no discordance between the quantum theory and the undulatory theory. But the new terms will presumably stay in when the equations are applied to problems of interaction between matter and ether, so that h may be expected to play a part in all such phenomena.

Professor LORENTZ said that he agreed in the main with Mr. Jeans. It seems indeed that, in order to account for the facts of radiation, we must introduce a discontinuity of one kind or another, and that, at present, no hypothesis is more suitable than the assumption of definite quanta of energy.

The theory may, however, be presented in different forms, which are best understood if, in the systems with which we are concerned, we distinguish *three* parts, viz., (1) molecules and atoms, between which and the ether there is no direct interaction, and which, for the sake of convenience, we may call 'matter'; (2) some kind of 'vibrators,' each having a frequency of its own; and (3) the 'ether.' The vibrators must be considered as carrying electric charges, in virtue of which they can give rise to electro-magnetic vibrations propagated in the ether, and can, conversely, be set in motion by electro-magnetic waves, the simplest type of vibrator being given by a single electron, moving about its position of equilibrium under the influence of a quasi-elastic force. On the other hand, the vibrators can exchange energy, by collisions or otherwise, with the material particles, so that they constitute a link between matter and ether.

It need hardly be said that the distinction between the particles of matter and the vibrators is somewhat artificial; it may well be that in some cases the emission and absorption of heat is not due at all to vibrators having a definite period. It should also be remarked that, if we use the terms in the above sense, a mono-atomic gas consisting of uncharged molecules must be said to contain matter only, whereas a crystal composed of charged atoms arranged in definite positions of equilibrium would be entirely made up of vibrators. If, however, such a crystal were exposed to the bombardment of gaseous molecules, we should again have to deal with a system formed of the first two parts of which we have spoken.

As to the third part, we may apply to it the time-honoured name of 'ether,' without discussing the fitness, in the present state of science, of maintaining the ideas that were originally associated with the word. The principle of relativity leads us to consider the question whether the ether has so much of substantiality that one can speak of the motion of a body relatively to it. For the present purpose this is irrelevant, and 'ether' is merely a word, for which we might as well substitute 'vacuum.'

Now it must, I think, be taken for granted, that the quanta can have no individual and permanent existence in the ether, that they cannot be regarded as accumulations of energy in certain minute spaces flying about with the speed of light. This would be in contradiction with many well-known phenomena of interference and diffraction. It is clear that, if a beam of light consisted of separate quanta, which, of course, ought to be considered as mutually independent and unconnected, the bright and dark fringes to which it gives rise could never be sharper than those that would be produced by a single quantum. Hence, if by the use of a source of approximately monochromatic light, we succeed in obtaining distinct interference bands with a difference of phase of a great many, say, some millions, of wave-lengths, we may conclude that each quantum contains a regular succession of as many waves and that it extends therefore over a quite appreciable length in the direction of propagation. Similarly, the superiority of a telescope with wide aperture over a smaller instrument, in so far as it consists in a greater sharpness of the image, can only be understood if each individual quantum can fill the whole object-glass.

These considerations show that a quantum ought at all events to have a size

that cannot be called very small. It may be added that, according to Maxwell's equations of the electro-magnetic field, an initial disturbance of equilibrium must always be propagated over a continually increasing space.

We might now suppose that the exchange of energy between a vibrator and the ether can only take place by finite jumps, no quantity less than a quantum being ever transferred to the medium or taken from it. Something may be said, however, in favour of the opposite hypothesis of a gradual action between the ether and the vibrator, governed by the ordinary laws of electro-magnetism. Indeed, it has been shown already, in Planck's first treatment of the subject, that by simply adhering to these laws, one is led to a relation between the energy of the vibrator and that of the black radiation, of whose validity we have no reason to doubt.

The problem solved by Planck admits of a wide generalisation. Instead of his linear vibrator, we may conceive a body having any number of degrees of freedom and capable therefore of vibrating in many different fundamental modes. If such a body carries some distribution of electric charges and is surrounded by black radiation, it will be set in motion in all its modes, and the energy of each vibration is found to be

$$\frac{\lambda^4}{8\pi}f(\lambda),$$

where λ is the wave-length and

$$f(\lambda)\,d\lambda$$

the energy of the black radiation per unit volume, belonging to rays with wave-lengths between λ and $\lambda + d\lambda$. But, by Planck's equation, which we may use as an empirical formula representing the actual distribution of energy,

$$f(\lambda) = 8\pi \mathrm{RT}\lambda^{-4}.\frac{x}{\epsilon^x - 1},$$

where x has the same meaning as in Mr. Jeans' formulæ, so that the energy of the body for each normal vibration becomes

$$\mathrm{RT}.\frac{x}{\epsilon^x - 1}.$$

This result shows the intimate connection between two of the expressions given by Mr. Jeans, and it justifies Debye's method for calculating the specific heat of a solid body. The important point is that it can be obtained without the introduction of anything beyond the ordinary electro-magnetic equations.

So far, the hypothesis of quanta is found to be unnecessary or even inadmissible, and perhaps the best course we can take will be to limit it to that part of the theory in which we consider the equilibrium between the vibrators and the material particles. It is possible that we shall be able after all to work out a satisfactory theory on the basis of certain assumptions involving a discontinuous transfer of energy between these two parts of the system. Of course, when we try to do so, it may be very helpful to have before us some special model of the structure and properties of a vibrator, such as that which Sir J. J. Thomson brought forward yesterday. Some years ago, Dr. E. A. Haas, of Vienna, proposed another interesting model, which, however, does not illustrate an important feature that is explained by Sir J. J. Thomson, viz., the proportionality between the magnitude of a quantum and the frequency of vibration.

Following Mr. Jeans, I must finally say some words on the equilibrium between the radiation and a system of free electrons. Starting from Drude's theory of the metallic conduction of electricity, I once calculated both the absorption and the emission of rays by a thin sheet of metal. By combining the two results I obtained an expression agreeing with Lord Rayleigh's radiation formula, which, as is well known, holds for low frequencies. My calculations had been expressly limited to these, and I therefore hoped for some time that it would be possible to deduce Planck's equation by leaving aside the restriction, going more deeply into the details of the problem. At present we may be

sure that this would be of no use at all, and that, whatever be the motion of the electrons, we shall always fall back on Lord Rayleigh's formula, so long as we apply the old electro-magnetic equations. This is a most serious difficulty, and we cannot escape from it by saying that perhaps the free electrons contribute but a small part to the total radiation. It is inadmissible that, in addition to a mechanism leading to Planck's formula, there should be another, however feeble be its influence, that would give us a different law. Moreover, it must be kept in mind that the explanation of an electric current by the theory of electrons requires at all events *some* free mobility of these particles, and that we come across the same difficulty when we consider an electrolytic substance partly filling an enclosed space. The motion of the ions would produce a field of radiation that would certainly be determined by Lord Rayleigh's formula if the old theories were true.

It will, therefore, not suffice to introduce the notion of quanta into the theory of vibrators, but, as Mr. Jeans has suggested, we shall most probably have to modify Maxwell's equations for those parts of space where there is an electric charge.

(Added after the discussion.) Even if we confine ourselves to the equilibrium between the radiation and a vibrator, there is one problem in which the old theory encounters a difficulty. It is that of the motion of translation, the Brownian movement, as we may call it, which the vibrator will take under the influence of a field of radiation corresponding to a definite temperature. One would expect its kinetic energy to be equal to that of a gaseous molecule at the same temperature. Einstein and Hopf have found, however, a much smaller value.

Professor E. PRINGSHEIM: It is very satisfactory that Mr. Jeans now has abandoned his former doubts of the results found by experiment. So this discussion on radiation seems to have great importance in showing that on the general question there is an agreement between all physicists who work in this matter, although opinions may differ in the details. The theoretical difficulties and the chief points where theory requires improvement have been pointed out by Messrs. Jeans and Lorentz. I wish to draw attention to the problems which are to be solved by experiments. First of all, there is still a remarkable disagreement between the different measurements of the universal constants of radiation, as well of the constant σ of Stefan's law as of the constant h of Planck's law. Here new experiments are necessary. Further, the laws of black radiation must be examined through a larger range of temperature and wave-length than has been done at present. Finally, the radiation of bodies other than black must be studied more and more. Here the metals have the greatest theoretical interest, since Aschkinass has shown how the distribution of energy in the spectrum of metals can be calculated by means of the laws of black radiation and Maxwell's electro-magnetic theory. And as the metals are the material used in modern types of incandescent lamps this question is also of great practical importance. The chief difficulty of these experiments consists in the determination of the true temperature of the radiating metals. Recently my friend, Professor O. Lummer, in Breslau, has suggested a method which seems to solve this problem in a very elegant way.

Professor A. E. H. LOVE: I am unable to accept the view that, in order to account for the facts about radiation, existing theories of dynamics and electrodynamics need to be supplemented by the theory of quanta. Part of the evidence in favour of this view has been derived from an application of the principle of equipartition of energy to a system consisting of ether and matter in an enclosure bounded by perfectly reflecting walls. Such a system has an infinite number of degrees of freedom, and the principle of equipartition cannot be applied without modification to any such system. The ethereal kinetic energy would be expressed by an infinite series of the form

$$u_1 + u_2 + u_3 + \dots \text{ ad inf.},$$

in which there is one term answering to each degree of freedom, and the order of the terms is that of increase of the corresponding frequencies. In order that an infinite series may represent ethereal kinetic energy, or anything else, it is necessary that it should be convergent. In order that it may be convergent, it is

necessary that all the terms which are far advanced in the order of the series should be very small compared with some of those which precede them. It is therefore impossible for all the terms to be equal as required by the principle of equipartition. If, however, the principle of equipartition is limited by the principle of convergence, it yields some information as to the distribution of energy in the spectrum of a black body. In so far as it is legitimate to regard the infinite series, by way of approximation, as the sum of a large, but finite, number of terms, the principle of equipartition should be applicable, also as an approximation, and it yields Lord Rayleigh's experimentally verified formula for the emissivity answering to long waves. The principle of convergence shows, on the other hand, that for short waves the curve obtained by plotting emissivity against wave-length should fall towards the origin, as it is known to do. But this principle yields no information as to the position in the spectrum of the longest waves for which Lord Rayleigh's formula fails to give a valid approximation.

The arguments on which the theory of quanta was founded cannot be regarded as satisfactory. Indeed, the most convincing evidence in favour of the theory would seem to be the agreement with experiment of M. Planck's formula, according to which the emissivity of a black body is given as a function of the wave-length λ and the absolute temperature T, by an expression of the form

$$A\lambda^{-5}(e^{B/\lambda T} - 1)^{-1},$$

where A and B are properly determined constants. It may, therefore, be pertinent to remark that from a mathematical point of view there must be infinitely many formulæ which would agree equally well with the experiments. In illustration of this statement, it may be mentioned that a formula proposed recently by A. Korn, according to which the emissivity of a black body would be given by an expression of the form

$$C\lambda^{-6}T^{-1}(e^{D/\lambda T} - 1)^{-2},$$

where C and D are properly determined constants, when tested arithmetically over a wide range, yields results showing just about as good an agreement with the facts as Planck's. It may be, however, that there is no simple formula, like those of Planck and Korn, which is applicable to all wave-lengths. However this may be, there seems to be no sufficient reason for regarding Planck's formula as expressing a law of Nature.

In further illustration of the contention that the resources of the ordinary theories are not exhausted, it may be pointed out that it is possible to extend to some additional cases the calculation, first carried out by H. A. Lorentz in the case of long waves, of the emissivity of a thin metal plate. He supposed the radiation to be generated in collisions between free electrons and atoms, and calculated the emissivity for waves of periods long compared with the times occupied in describing free paths. For this calculation he required to evaluate approximately a certain integral. Such an evaluation can be effected also in the case of waves which have their periods comparable with the times occupied in describing free paths, and, for a number of laws of variation of the acceleration during a collision, in the case of waves which have their periods comparable with the times occupied by collisions. As the wave-length diminishes the emissivity of the thin plate at first increases, then reaches a maximum, and finally diminishes to zero; as the temperature rises the wave-length answering to the maximum emissivity diminishes, as would be expected. But there is no simple analytical formula which represents the emissivity of the thin plate over the whole range of wave-lengths.

Mr. Jeans: I do not think the mathematical question of the convergence of Professor Love's infinite series need be considered at all. If the series is arranged in order of descending wave-lengths we may say roughly that the equations of the classical dynamics demand that the energy should be transferred along the terms of the series from left to right, and no steady state can be attained until the terms are all equal. The time taken for the energy to reach the more distant terms can be approximately calculated: before we have got very far along the series it becomes a matter of millions of years. Let us then

consider, say, only the first $10^{10^{10}}$ terms: we have a finite series of terms, and until millions of years have elapsed the physical problem is perfectly well represented by this finite series, for which questions of convergence have no meaning.

Professor LORENTZ: In reply to Professor Love's interesting remarks, I should like to say that it is precisely one of the objects of the physical theory of radiation to explain why the energy of the black radiation can be represented by a convergent series. The old theories lead to a different result, but this in itself would not be a physical contradiction or impossibility; it would simply mean that all energy will in the end be transferred to the ether and that it will continually take the form of shorter waves, a really final state never being reached. Our aim must be to account for a true state of equilibrium, in which there is a finite ratio between the parts of the energy that are found in a ponderable body enclosed in an envelope and in the surrounding ether. We shall also have to assign a physical meaning to the universal constant h occurring in the formula by which Planck calculates this ratio.

Sir J. LARMOR derived the impression from the trend of the discussion that it would turn out that in the new low-temperature determinations there was nothing in direct conflict with the classical dynamical principles. The essential argument for equipartition among vibrational types of energy is, briefly, that these types enter similarly into the total energy, and thus, other things being indifferent, there is no reason that can be assigned to the contrary. They enter similarly merely because the energy is a sum of squares of their 'momentoids.' But other things may not be indifferent; for example, in the kinetics of a rotating atmosphere the distribution of energy must be modified so as to maintain constancy of the angular momentum as well as of the energy, giving as the result equipartition relative to the rotation instead of absolutely. Moreover, in an isolated region of æther there is no way open for any interchange of energy at all between one type of vibration and another; here also other things are *not* indifferent. The exchange must be effected through the mediation of material molecules. It is true that a single electron, moving erratically between complete reflections from the ideal impervious walls of the chamber, would suffice. But the structure of an electron, including the mechanisms by which it exchanges energy with the ether, is totally unknown. Such a fundamental fact as the pressure of radiation is involved in that structure; we can only establish it theoretically as pressure on systems of electrons; it must be transmitted by the ether in some way, but we do not know how, except by speculating, for it is a second-order phenomenon not involved in the Maxwellian linear scheme of equations. In the very intense kinetic phenomena in the mechanism of the electrons or molecules, by which they serve to transfer energy from one type of ethereal vibration to other types, the energy must be expressible as a sum of squares of definite momentoids if the transfer is to lead ultimately to equipartition. This restriction in its form is unlikely; the transfer may even be of a discontinuous character, involving release of electrons into freedom. The Planck formula for the constitution of natural free radiation may be obtained by statistical reasoning, strictly on the lines of Boltzmann's entropy theory for gases, in which atoms or vibrators are not considered at all, but the pressure of radiation is introduced instead, as I have tried to show (*Proc. Roy. Soc.* 1906); the only implication is that the process of interchange of ethereal energy between different vibrational types, by the mediation of matter, though unknown, must be such as to provide a pressure of radiation. If, then, there is no reason to press equipartition as regards free natural radiation, the atomic vibrations, which are set up by its agency and must be in equilibrium with it, are also absolved therefrom.

The new knowledge relating to specific heats at very low temperatures has already suggested most interesting speculations and tentative adjustments, and will certainly lead to definite expansion of our theoretical schemes; but it can be held that there is nothing in it that is destructive to the principles of physics which have led to so rich a harvest of discovery and synthesis in the past.

Mr. JEANS: As the time is so short, I must only touch on a very few of the many interesting points that have been raised.

With regard to Professor Love's suggestion that the radiation formula might be obtained by the old mechanics from an analysis of electron orbits, two remarks

may be made. If we proceed on the old mechanics we obtain the law of equipartition (Rayleigh's Law) as the final result, true for all wave-lengths; unless we assume also that the observed state is not one of true thermodynamical equilibrium.[1] If we make this additional assumption, a definite law can be obtained, but it is open to two fatal objections. First, since the electron orbits are different in different substances, the resulting law for black-body radiation is found to be different for different substances, in opposition to experiment; secondly, as a result of numerical calculation, it is found that to account for the observed law of radiation, the electron orbits and free-paths would have to be of a size which is quite incompatible with what we know as to molecular dimensions.[2]

With regard to Professor Lorentz's remarks on the possibility of making a distinction between 'matter' and 'vibrators,' surely the work of Debye has shown quite convincingly that any such distinction is purely fictitious. For it now appears that the oscillations of the 'vibrators' required by the theory of Planck are simply the elastic vibrations of the mass of matter as a whole. Whether we regard these as oscillations of vibrators or of matter is for us to choose, but it seems to be clearly proved that there is only one set of oscillations, and the bodies which oscillate are Professor Lorentz's 'vibrators' and 'matter' rolled into one.

DEPARTMENT OF GENERAL PHYSICS.

The following Papers were read :—

1. *Crystals and X-Rays.* *By* Professor W. H. BRAGG, *F.R.S.*

We know from recent experiment that X rays of wave-length λ can be reflected by a set of parallel crystal planes when the relation $n\lambda = 2d \sin \theta$ is fulfilled.

In this formula d is the distance between the consecutive planes, λ is the wave-length, θ is the angle between the planes and the incident or reflected ray, and n is a whole number. This principle leads to two distinct lines of research. The first is based on the original experiment of Laue. A pencil of heterogeneous rays is passed through a crystal slip and the various crystal planes reflect pencils from the primary beam, which pencils are allowed to fall upon a photographic plate. Each pencil consists of homogeneous rays of wave-length determined by the above relation. Since the various sets of planes have different values of d, heterogeneous rays are wanted in order that each set may be able to reflect. A bulb with a Pt anticathode has been generally used and is very suitable. By examining the distribution of the energy in the various spots on the photographic plate information can be obtained as to the position of the reflecting planes and their 'richness' in atoms.

The second method is based on the use of homogeneous rays. If the angle between the primary pencil and the crystal is gradually increased and the strength of the reflective pencil is measured by the ionisation it effects in a suitable chamber, any homogeneous pencil in the primary rays is reflected only at angles given by the formula. In this way a 'spectrum' of the primary rays is mapped out. Platinum anticathodes emit several lines in addition to the heterogeneous radiation, and are not so suitable for these experiments as rhodium or palladium; osmium and indium are still less suitable. The spectrum of the rhodium has one strong pencil of wave-length $0{\cdot}607 \times 10^{-8}$, and a weaker pencil of wave-length $\cdot 533 \times 10^{-8}$. Palladium has an exactly similar spectrum, but the wave-lengths are nearly six per cent. smaller. There is very little radiation of other wave-lengths from either bulb. When the spectrum of rhodium or palladium is mapped for various sets of crystal planes of various crystals we obtain measures of the spacing of the planes and so obtain data which help in the determination of crystal structure.

The diamond may be taken as an example. The spectrum reflected by the three important sets of planes show that the (100) planes are closest together of the three, that the (110) planes are more openly spaced, in the proportion of $\sqrt{2}$ to 1, and the (111) planes in the proportion $\sqrt{3}$ to 1. These latter show a further important feature

[1] *Phil. Mag.* June 1909. [2] *Ibid.* July 1909.

in the entire absence of a second order spectrum. That is to say, there is no reflection at an angle θ for which $\sin\theta = \frac{\lambda}{d}$, though it does occur when $\sin\theta = \frac{\lambda}{2d}$ or $\frac{3\lambda}{2d}$ or $\frac{2\lambda}{d}$ or $\frac{5\lambda}{2d}$. Fluor-spar shows the same effect, and zinc blende approximates to it. The interpretation is that the (111) planes are not equally spaced, but there is an alternation of spaces, one of which is three times the other. The spectra also tell us the actual values of all the spacings. When all the information is put together we find that the element of volume of the diamond is a face-centred cube; a cube having, that is to say, a carbon atom at each corner and one in the middle of each face. In the same cube are also four carbon atoms at the centres of four of the eight small cubes into which the large cube may be divided. The structure may also be described as consisting of two interpenetrating face-centred cube lattices, one of which can be derived from the other by translating it in the direction of the diagonal through a distance equal to one quarter of that diagonal.

In the same way zinc blende is shown to have exactly the same structure as the diamond, except that one of the two lattices consists entirely of zinc atoms, and the other of sulphur. In the case of fluor-spar there is a face-centred lattice of calcium atoms, fluorine atoms being placed at the centres of all the eight small cubes. Iron pyrites, sulphur, calcium, and other crystals have also been examined by these methods. Some of them show the most remarkable variations in the strengths of the spectra of the various orders.

The method of the Laue photograph has also been applied to the examination of the diamond structure; the results entirely agree with those of the reflection method.

2. *On Lightning and Protection from it. By* Sir J. LARMOR, *F.R.S.*

The *rationale* of electric discharge in a gas is now understood. When a small region becomes conducting through ionisation by collisions in the electric field it should spread in the direction in which the field is most intense, which is along the lines of force. Thus the electric rupture is not a tear along a surface but a perforation along a line. This is roughly the line of force of the field: the electro kinetic force induced by the discharge, being parallel to the current, does not modify this conclusion. A zigzag discharge would thus consist of independent flashes, the first one upsetting adjacent equilibria by transference of charge. Successive discharges between the same masses would tend to follow the same ionised path, which may meantime be displaced by air currents.

If the line of discharge is thus determined by the previous electric field, the influence of a lightning-conductor in drawing the discharge must be determined by the modification of this electric field which its presence produces. For a field of vertical force, such as an overhead cloud would produce, it may be shown that the disturbance caused by a thin vertical rod is confined to its own immediate neighbourhood. Thus while it provides a strong silent discharge from earth into the air, it does not assist in drawing a disruptive discharge from above—except in so far as the stream of electrified air rising from it may provide a path. It is the broader building, to which the rod is attached, that draws the lightning: the rod affords the means of safely carrying it away, and thus should be well connected with all metallic channels on the building as well as with earth. It is the branching top of an isolated tree that attracts the discharge; a wire pole could not do so to a sensible degree. Separate rods projecting upwards from the corner of a building do not much affect the field above it, but if they are connected at their summits by horizontal wires, the latter, being thus earthed, lift up the electric field from the top of the building itself to the region above them, and thus take the discharge which they help in attracting, instead of the building below them. Similarly, when the lines of force are oblique to a vertical rod, its presence does somewhat modify the field and protect the lee side; but generally the presence of a rod should not ever be a source of danger, unless the ionised air rising from it provides an actual path for discharge.

Department of Mathematics.

The following Papers were read :—

1. *The Dynamics of a Globular Stellar System.* *By* Professor A. S. Eddington.

In considering the gravitational attraction of the whole stellar system on a star, it seems probable that we may neglect the part due to the chance distribution of stars in the immediate neighbourhood, and consider only the smoothed central force. We have thus to study a new kind of dynamics, which resembles molecular dynamics in being a statistical subject, but differs from it in that there is nothing corresponding to the 'encounters' of molecules. The first problem to attack is the determination of the different possible distributions of velocity which correspond to a steady state. A number of the simpler cases are worked out in the paper. It is of particular interest to find a system in which there is strong preferential motion to and from the centre, compared with the transverse velocities (following Professor Turner's suggested explanation of the two star streams). It is a little difficult to reconcile preferential radial motions with a finite density at the centre of the system; but systems satisfying both these conditions seem to be possible.

2. *The Expression for the Electrical Conductivity of Metals as deduced from the Electron Theory.* *By* W. F. G. Swann, *A.R.C.S., D.Sc.*

Drude's formula $\sigma = \frac{ne^2\lambda v}{4a\theta}$ for the electrical conductivity σ was developed on the assumptions that all the electrons move with the same velocity v, and that there is no persistence of velocity after collision. Though more elaborate formulæ have since been deduced by different methods, the above formula is not without interest, in that it corresponds to a better ratio for the electrical to the thermal conductivities than is given by some of the more elaborate formulæ. The object of the present paper is, however, to show that the assumptions on which it is based do not lead to it, but to the formula $\sigma = \frac{ne^2\lambda v}{3a\theta}$ which is much less in agreement with the facts

In the deduction of Drude's formula it is assumed

(1) that since the velocity given by the field X to an electron while travelling over its mean free path λ is $\frac{Xe\lambda}{mv}$, the average velocity given by the field to the electrons is $\frac{Xe\lambda}{2mv}$;

(2) that the average velocity of the electrons parallel to the field is the average velocity which the field has created in the electrons.

The first assumption is equivalent to the assumption that the electrons to be found in any element at any instant are on the average in the middle of their free journey, and that they have consequently at that instant travelled on the average a distance $\frac{\lambda}{2}$. Although this is apparently obvious, it is not true. The true average distance turns out to be λ. Correcting for this we should obtain $\sigma = \frac{ne^2\lambda v}{2a\theta}$.

The objections with regard to assumption (2) will perhaps be clear when it is remarked that if all the electrons to be found per cc. at any point O were suddenly robbed of the velocity which the field had given them, while their positions were left unchanged, we should still have a resultant current, for if the field, for example, urges the electrons from left to right, and if we draw a plane through O perpendicular to the field, and if, further, we consider the action of the field in bending the paths of the electrons, we see that the electrons which have come to O from any element to the right of the plane started out more nearly parallel to X than the electrons which have come from the element symmetrically situated to the left of the plane. When due

allowance is made for this fact, it becomes necessary to subtract from the quantity $\frac{ne^2\lambda v}{2\alpha\theta}$ an amount equal to $\frac{ne^2\lambda v}{6\alpha\theta}$, so that the resultant conductivity is $\sigma = \frac{ne^2\lambda v}{3\alpha\theta}$. It is quite an accident that the two corrections discussed act in opposite directions. If they had been in the same direction the effect would have been even greater.

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MONDAY, SEPTEMBER 15.

Department of General Physics.

Joint Discussion with Section G on the Investigation of Complex Stress Distribution

The Construction of Large Polarising Apparatus, &c. *By* Professor E. G. Coker.

Large polariscopes for directly viewing objects in plane and circularly polarised light may be constructed by methods described in a former paper,[1] but for quantitative work and for projection on a screen it is more convenient to adopt an arrangement in which a beam of light from an arc-lamp is rendered parallel by a lens, and is afterwards polarised by reflection from black glass, or by refraction through a series of clear glass plates. The analyser may be of the same construction on a similar scale, and the addition of quarter-wave plates allows an object to be viewed free from the black cross-effect.

In this manner a parallel beam of light can be obtained capable of showing objects several inches in diameter. The field of view may be still further increased by producing a diverging polarised beam, and interposing a converging lens between the object and the analyser.

It is, however, essential that the converging lens shall be quite free from internal stress to avoid distortion of the optical effect.

An arrangement of two plano-convex lenses, one on each side of the object, has also been proposed by Mesnager[2] for the purpose of increasing the field of view with the usual arrangement of Nicol's prisms.

The following Papers were then read :—

1. *A Theory of Luminescence and the Relation between Luminescence and Pure Temperature Radiation.* *By* Professor E. Pringsheim.

With practical certainty we can say: every phenomenon where Kirchhoff's law is found to hold is a case of pure temperature radiation, every one where Kirchhoff's law is not fulfilled is a phenomenon of luminescence. Now where the laws of black radiation are known we are able to answer with all precision the question whether Kirchhoff's law holds or not in a given case. The experiments of several authors on metallic vapours glowing in a Bunsen flame have shown that the black temperature is the same for the different spectral lines observed in the same flame. So it is very probable that Kirchhoff's law holds in this case. For an exact proof, however, it needs still to be demonstrated that the black temperature is identical with the true temperature of the gas. This proof has been given by two sets of experiments made in the physical laboratory of Breslau, first by Mr. Gibson for thallium vapour glowing in an evacuated

[1] 'The Design and Construction of Large Polariscopes,' by Professors E. G. Coker and S. P. Thompson, *The Proceedings of the Optical Convention*, 1912.

[2] 'On the Measurement of Internal Tension in Solid Bodies and their Application,' by A. Mesnager, *International Association for Testing Materials*, Budapest Congress, 1901.

Quay tube, and quite recently by Miss Hedwig Cohn for metal vapours in flames. So these processes are of the type of pure temperature radiation.

In order to bring this result into agreement with former experiments made by myself and by others, I put forward the hypothesis that in general two processes must work together for originating the spectral emission of a gas; by the first the centres of emission (electrons of dispersion) must be created, by the second these centres must be excited to emission. Even when—as it is in the case of pure temperature radiation—the excitement is due to the collisions of the atoms containing a vibrator with other molecules or atoms, whose average kinetic energy is a function of temperature only, the creation of the vibrators may be due in full or partially to processes of quite another nature; for instance, to chemical or electrical actions.

In the case of luminescence we can follow a method quite analogous to that given by Planck in his theory of black radiation. In the state of thermodynamical equilibrium according to Planck the average energy of a resonator of the frequency ν at the absolute temperature T is given by

$$U = \frac{h\nu}{e^{\frac{h\nu}{RT}} - 1} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1),$$

where h and R are the well-known constants. This average energy in the case of temperature radiation is given to the resonator by the permanent exchange between its own energy and the kinetic energy of the molecules. The only term in the formula connected with the energy of molecules is the term RT, which is proportional to the average energy of the exciting impulses. In the case of luminescence a stationary state of equilibrium can also take place in all the phenomena, where the emissivity E_λ and the absorption power A_λ are independent of the density of radiation. (Therefore our theory cannot be applied to the phenomena of phosphorescence and fluorescence.) When this state of equilibrium is established, the emission will arise by the interchange of energy between the exciting impulses and the vibrating resonators. Provided that all radiating resonators are excited by a similar mechanism following the same law, the average energy of a resonator will be given by

$$U = \frac{h\nu}{e^{\frac{h\nu}{f(i)}} - 1} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2),$$

where $f(i)$ is a definite function of the intensity i of the process by which the luminescence is excited. For a body which follows the equation (1) according to Kirchhoff's law we would have:

$$\frac{E_{\lambda T}}{A_{\lambda T}} = e_{\lambda T}.$$

When in equation (2) we put

$$f(i) = RT_1,$$

it takes the form of equation (1) for the average energy of a resonator in the black radiation of the temperature T_1. In this way it follows that in the state of equilibrium characterised by equation (2) we must have:

$$\frac{E_\lambda}{A_\lambda} = e_{\lambda T_1} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3).$$

As A_λ and E_λ are presumed to be independent of the established state of radiation, $\frac{E_\lambda}{A_\lambda}$ must be a quantity characteristic for the given phenomenon of luminescence, given by the emissivity $e_{\lambda T_1}$ of a black body of the temperature T_1, even when there is no state of equilibrium in the luminescent body.

So we have to expect very near parallelism between the phenomena of luminescence and of temperature radiation, as is observed in many cases. The difference between these two classes of phenomena seems to be much smaller than we thought before. On the other hand, when we find that in a phenomenon of luminescence the equation (3) leads to the same temperature T_1 for different spectral lines, we can conclude that the mechanism of emission of different wave-lengths may be the same.

Independently of all hypothesis we may define what I call the 'specific temperature' of a radiating body for the wave-length λ to be the temperature T_1, at which the emissivity $e_{\lambda T_1}$ of the black body equals the fraction $\frac{E_\lambda}{A_\lambda}$ for the radiating body. (Mr. E. Bauer defined the same quantity and called it 'temperature of emission.') The fraction $\frac{T_1 - T}{T}$ would give us a scale for the degree of luminescence.

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2. *Resonance Spectra under High Dispersion.* *By* Professor R. W. Wood.

3. *A Theory of Magnets.* *By* Professor S. B. McLaren.

It is my object to recall some difficulties of magnetic theory and to suggest how they may be escaped.

The history of magnetic science divides into an ancient and a modern period, the times before and after Ampère. In the earlier period the fundamental idea used is that of a magnetic substance; after Ampère this idea disappears. The magnet is now regarded as a whirl of electric particles or electric fluid. In modern electro-magnetic theory all substance is electric; with Lorentz, for example, matter is the electric fluid.

Thus Ampère may claim to have given what previously did not exist, a theory of magnets. Before him the existence of molecular magnets was the starting-point; any explanation of magnetic phenomena, as, for example, Poisson's account of magnetic induction, has to begin with matter whose elements are already magnetised. Poisson, I may remind the reader, can only account for paramagnetism; of diamagnetic phenomena there is no obvious explanation. I wish to point out that the modern electro magnetic theory has its own difficulties. It cannot take over unmodified Poisson's way of viewing the phenomena of magnetic induction.

It is true that the magnetic field due to a magnet is the same as that due to a rotating electric charge; it is true also that the resultant force exerted by the field on the charge is the same as that which it exerts upon the magnet. But it by no means follows that this force produces the same results in the two cases. And one fact sufficiently establishes a difference. A magnetic field does work upon the magnet in changing the direction of its axis, or the magnet in that field has potential energy; on the other hand, the same field can do no work by changing the axis of rotation of the electric charge, because the force on each element is at right angles to its motion. Take in particular a spherical distribution of charge rotating about any diameter. Set up a steady magnetic field, the only effect is to superimpose upon the original rotation about an axis fixed in the charge another rotation about the magnetic lines of force, with an angular velocity simply proportional to that force. This second motion accounts for diamagnetism, but there is no tendency for the axis of rotation fixed in the charge to approach the magnetic lines. The diamagnetic field is independent, as it ought to be, of the temperature, but no paramagnetic field is created.

The difficulty has been remarked by Lorentz, Voigt, J. J. Thomson, N. Bohr, and, I doubt not, by others. It is not, however, generally recognised that in such a theory of magnetic induction as Langevin's we are back at the ancient postulate of magnetic substance.

The difficulty may, I think, be evaded by moving still further from the old point of view as well as by returning to it. We may give up not only magnetic substance, but electric substance as well.

I assume the electro-magnetic field defined by two vectors E and H. This field is not all space; it is bounded by closed surfaces within which E and H do not exist. The space within these is 'matter,' without them 'æther.' All formulæ are to be deduced from the principle of least action. Following Larmor, suppose that the action, in so far as it involves E and H, is identified with the expression

$$(8\pi)^{-1} \iiiint (H^2 - E^2)\, dv\, dt,$$

dv an element of volume of dt of time. It may be shown that the action is a minimum consistent with the conditions

$$\frac{d\,E}{d\,t} = c \text{ Curl H} \quad Div \text{ E} = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

If we have also

$$\frac{d\,H}{d\,t} = - c \text{ Curl E} \quad Div \text{ H} = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

(1) and (2) are the electro-magnetic equations. And the necessary conditions at any boundary of the electro-magnetic field are just those which obtain at a perfect reflector.

(1) and (2) possess integrals of two different types. The quantity

$$\iint \text{E}\, d\,s$$

is a constant where ds is any element of area of a closed surface. Thus the electric induction over any closed surface is constant, and any portion of matter therefoie carries a constant change which is yet not an electric substance. Further, suppose the material surface is multiply connected like an anchor ring. The magnetic induction across the aperture is constant, remembering that at the material surface the conditions are the same as those at a perfect reflector. Hence the anchor ring may behave like a permanent magnet of constant moment. The external field produces a tension of amount

$$\frac{1}{8\pi}\left(\text{E}^2 - \text{H}^2\right)$$

in unit area of the surface of matter. This tension accounts for all the observed magnetic and electric forces Magnetic induction is now explicable, because this tension acting upon matter has replaced the force acting upon electric fluid. The molecular magnetic field is not to be explained as due to the circulation of electric current sheets. That is merely a mathematical device.

There remains the question what constraints must be applied to the material surfaces that they may be stable. That problem is not solved in any theory; it is no more or less soluble in the present theory than in any other.

DEPARTMENT OF COSMICAL PHYSICS.

1. *Radial Motion in Sun-spots.* By C. E. ST. JOHN.

This investigation was undertaken in 1910 with the 60-foot Tower telescope and the 30-foot spectrograph on Mount Wilson. Mr. Evershed's announcement of the discovery of displacements of the Fraunhofer lines in the penumbræ of spots was made in 1909 (Bulletin XV., Kodaikanal Observatory). These displacements were referred by him to movements of the vapours of the reversing layer outward from spots and tangential to the solar surface. His observations were made by placing the slit of the spectrograph across the spot and coincident with the radius of the solar disk passing through the centre of the umbra. Under these conditions many solar lines became curved somewhat like the letter S when the spot was between a quarter and half-way from the limb to the central meridian. The measurements were made by determining the angle through which the observed sections of the lines were tilted and calculating the displacement. A preliminary investigation at once confirmed Mr. Evershed's observations, but it seemed desirable to have a method of measuring the displacements directly. An occulting arrangement was devised by which the spectra of the outer edges of the penumbra directed towards the limb and the centre of the disk respectively were obtained side by side upon the photographic plate. By this arrangement the displacements to be measured were doubled, and the measurements could be made directly with a high degree of accuracy. An extended region of the spectrum was examined, and some 500 lines were observed. When the data were

assembled three points became at once evident—namely, (1) the displacements generally indicated an outflow of the solar vapours and were intimately related to the intensity of the lines; (2) the very strong lines were displaced in the opposite direction, and then showed a dependence upon intensity the reverse of that shown by the lines of moderate and low solar intensity; (3) the displacements were distinctly greater for lines in the red than for lines in the violet, pointing to a close relation between the displacements and wave-length. In fact, the differences nearly all disappeared when the displacements were reduced to a common wave-length and the comparison was made between lines of equal intensity. The residuals disappeared when allowance was made for the greater depths to which one can see into the sun by light of long wave-length, because of the lessened scattering of the long waves. This proportionality between displacement and wave-length points to the Doppler effect, and tends to strengthen greatly the explanation suggested by Evershed.

When the iron lines from intensity 00 to 10 are arranged in the order of intensity the displacements form a remarkably systematic series, which I have called the *Iron scale*. The variation of displacement with intensity is plainly evident, even without reduction to a common wave length, and was noticed before such reduction, and even when only a limited region of the spectrum had been examined, but it shows with great regularity where the displacements are reduced to a common wave-length.

The Iron Scale λ 5000.

Intensity.	00	0	1	2	3	4	5	6	7	8	10
Displacement	034	·030	·028	·025	·023	·021	·019	·016	·012	·009	·004
Vel. km./sec.	2 04	1 80	1·68	1·50	1·38	1·26	1·14	0·96	0·72	0·54	0·24

This scale is based upon nearly 200 iron lines, but a similar gradation appears in the case of any element represented by several lines.

In the case of strong lines the march of the phenomenon is equally striking and suggestive :—

Strong Lines λ 5000.

Element	Si	Al	Na	Mg	Hγ	Hα	Ca (H_3, K_3)
Intensity	12	15–20	20–30	20–30	20	40	
Displacement	000	·000	–·006	– 012	– 033	–·050	–·063
Vel. km/sec.	0·00	0·00	–0·36	–0·72	– 1·98	–3 00	–3·78

The negative sign indicates that the displacements are such as to imply an inflow of these high-level vapours into the spot, and if the assumption be made that the lines of low intensity have their origin at relatively great depths in the solar atmosphere, and that, consequently, the displacements are a function of the depth, we can get the distribution in a vertical section of a spot. The maximum velocity inward occurs at the highest level, and decreases as the depth increases until the level of zero velocity is reached; the motion then becomes an outward one, and the velocity increases with depth. These movements of the vapours do not form a complete system, as a high velocity inward occurs where the density is low, and a high velocity outward where the density is relatively great and the masses involved are unequal and the kinds of matter are unlike. The type of vortex indicated is that of the terrestrial tornado. There is a whirling upward rush from the interior of the sun, which spreads out radially with rapidly decreasing velocity tangential to the solar surface, and entrains with it the gases of the reversing layer. The actual vortex is deep-seated, the outflow into the reversing layer being a portion of the upper part of it, the inflow from the chromosphere being a secondary effect, a superficial indication of the underlying vortex in which the magnetic field originates.

For any given element the displacements decrease with increasing line-intensity, but for lines of equal intensity the absolute displacements differ from

element to element in general. Comparison has been made in each case with the iron scale, as shown below, for titanium, lanthanum, and cerium :—

Intensity	Ti—Fe	La—Fe	Ce—Fe
1	−0·002	+0·003	+0·007 Ang.
2	−0·003	+0·003	
3	−0·002	+0·007	+0·007
4	−0·004		
5	−0·004		
Weighted Mean .	−0·0026	+0·0033	+0·007

On the assumption that the displacements may be used as a criterion of level, the heavy elements lanthanum and cerium are low-level elements. By comparing all the elements with iron a distribution of the elements in the solar atmosphere is found that resembles that in the terrestrial atmosphere. As one penetrates the solar atmosphere from without the sun he would first encounter 'that form of calcium vapour that produces the H and K lines'; to this is successively added hydrogen and the vapours of magnesium, sodium, iron, &c., each increasing in absolute density with the depth until in the lowest portion of the reversing layer occur also the vapours of all the elements whose lines appear in the solar spectrum. The indicated distribution confirms that shown by Adams' measures of the solar rotation, and is in harmony with a wide range of solar observations that, taken separately, have shown indications of differences of level, such as the flash spectra, the weakening and strengthening of the lines in spots, the differences between centre and limb spectra, and the variation of the magnetic field due to the spot vortex with level. From this point of view the displacements of the Fraunhofer lines in the penumbræ of sun-spots give a means of sounding the solar atmosphere and of assigning relative levels to the sources of the lines, and open the way to further solar research.

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2. *On the Fourier Sequence as a Substitute for the Periodogram.* *By* Professor H. H. TURNER, *F.R.S.*

1. The use of the periodogram formed the main topic of Professor Schuster's Address to the Sub-section of Cosmical Physics in 1902. Hence it is appropriate that any alternative procedure should be brought before Section A.

2. It is suggested that the Fourier coefficients should be calculated for exact submultiples of the whole available period of observation, and for these only The advantages of this procedure are :—

(*a*) That it is *necessary*. Since it is only a portion of the procedure advocated as necessary by Professor Schuster, this will probably be conceded.

(*b*) That it is *sufficient*. It can readily be shown that the coefficients for any other period can be deduced from these Fourier constituents.

(*c*) That it is *convenient in practice*. It directs attention to definitely specified periods, whereas the method of the periodogram proceeds by trial and error, or some equivalent.

(*d*) It is *instructive*, especially in showing what will remain if any single periodicity or group of periodicities is eliminated from the observations.

The first fifty-four terms of the series for sun-spots have been calculated and the calculation of other terms is being undertaken.

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3. *Photographic and Spectrographic Arrangements of a Reflector.* *By* J. H. REYNOLDS.

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4. *Solar and Terrestrial Magnetic Disturbances.* *By* REV. A. L. CORTIE.

Sun-spots are not only indices of the general state of solar activity, but are also most frequently the centres of disturbed regions covering considerable areas on the sun's surface. The zones of sun-spot activity are also closely connected

with the equatorial rays of the sun's corona, which are such a characteristic feature of the corona at times of maximum solar activity. Regions of sun-spot activity, with the associated phenomena of faculæ, flocculi, and prominences, not unfrequently persist for several solar rotations. In a recent series of papers published in the 'Monthly Notices R.A.S.' (vol. lxxiii., nos. 1, 3, 6, 7) several such regions were discussed, which were also associated at each synodical return relatively to the earth, with series or batches of magnetic storms. Sometimes a set of consecutive magnetic disturbances will occur accompanying the transit of a region of solar disturbance across the disc, and, after an interval of two or three days, other isolated storms, corresponding to positions of the solar disturbance widely different in longitude relatively to the central meridian of the sun. Such phenomena point to the conclusion that the mode of propagation of the solar influence, which conditions the occurrence of terrestrial magnetic disturbances, is not in the form of a single cathodic discharge of particles, but rather of a divergent pencil of stream lines emanating from a focus of activity. The coronæ of the eclipses of 1893, 1898, 1905, and 1908 were characterised by bunches of divergent equatorial rays, the radiant-points or areas of which were identified with regions of long-continued sun-spot activity, which were in their turn associated with synodical series of magnetic storms.

A region of sun-spot disturbance was observed in 1910 from August 3 to October 24, the spots being confined to a belt between mean longitudes 64° to 48°, and latitude $-13°$ to $-16°$. Regions of long-continued sun-spot activity are generally in the form of narrow strips on the sun's surface. At the third appearance of this particular group of spots another group broke out just in advance of it, as so frequently happens, and the two groups together formed a fine curved stream nearly 20° in length, quite visible to the naked eye. The life-history of the combined groups can be followed from the Greenwich and Stonyhurst records, and that of the great area of the accompanying flocculi from the Tortosa observations. Besides compact flocculi centred on the groups, there was a region of diffused flocculi which spread to the north-west of the sun-spots. When the combined groups were visible on the sun's disc, September 26 to October 9, the whole disturbed region was covered with calcium flocculi. The accompanying prominences are discussed by Mr. Slocum in his paper 'The Attraction of Sun-spots for Prominences,'[1] and by Mrs. Evershed in 'Some Types of Prominences Associated with Sun-Spots.'[2] The prominences which were active from August 2 to November 5, extended on October 8 from $+6°$ to $-37°$ on the W. limb, and on their reappearance on the E. limb on October 22, when the spot disturbance was dying out, from $+12°$ to $-36°$. The heliographic latitude of the earth varied from $+6.0$ to $+5.1$ in the period August 3 to October 24. The first appearance of the group was marked by one great and two moderate magnetic storms, the second by two moderate, the third—that of the combined groups—by three great and five moderate, and the last by one great and three moderate, containing several synodical series of storms. The accompanying prominences were, according to Mrs. Evershed, in the form of radiating streaks, which is characteristic of the type associated with sunspots. If such radiating streaks represent the stream lines of the solar influence active in magnetic storms, they conform in their structure to the coronal rays already identified as connected with sun-spot areas and accompanying series of magnetic storms. Mr. Slocum also photographed rays disposed radially to the spot centres.

5. *A Temperature See-saw between England and Egypt.* *By* J. T. Craig.

6. *Possible Methods for Measuring the Amount of Atmospheric Pollution, &c.* *By* Dr. J. S. Owens.

The following methods were considered :—

1. Filtering a measured volume of air through a cotton or asbestos wool filter and weighing the filter before and after. This method was used by Mr.

[1] *Astrophysical Journal*, xxvi., no. 4.
[2] *Monthly Notices R.A.S.*, lxxiii. 6.

Russell for the Meteorological Office some years ago, and appeared to give good results. It requires considerable technical skill and has inherent difficulties, such as moisture in the wool; it is doubtful if it would give sound results, except perhaps in very impure air, as during a smoke fog. It also requires elaborate apparatus. The method is described by G. W. J. Russell in 'The Monthly Weather Report,' 1884 and 1885, by Cohen in 'J.S.C.I.,' 1887, and by F. Clowes in 'J.S.C.I.,' 1903.

2. All rain or other deposit falling on a gauge of known area may be collected, evaporated, and the residue weighed and analysed. This method was used in the investigations made by 'The Lancet' about two years ago to get the soot fall of London. It does not, strictly speaking, give the amount of air impurity, but the amount which falls on a given area (*a*) in rain, snow, &c.; (*b*) during dry weather; (*a*) and (*b*) are not separated but estimated together. The apparatus used may be very simple, and it is now adopted by the Committee for the Investigation of Atmospheric Pollution.

3. Aitken's Dust Counter. This is an instrument devised by Mr. John Aitken for counting the number of dust particles in air. It is described in 'Trans. R.S.E.,' Vols. XXX. to XXXVI. No attempt is made to obtain the composition of the dust particles.

4. Glass plates may be exposed to the air for a certain time, then washed in water and their opacity measured. This method was devised by Professor Cohen and used in Leeds. It appears to be useful only for catching matter which will stick to a glass plate, *e.g.*, tarry soot. It would seem also that the indication given must be affected by the amount of tar present in the smoke of a city; *i.e.* if there is not sufficient tar present to make the deposit stick the indication will be too low. It aims only at comparative results.

5. A jet of air may be caused to strike a glass plate coated by some sticky substance, and the opacity measured. This method may be used either:—(*a*) By causing the air jet to play on the glass for a fixed time and then measuring the increased opacity by comparison with a calibrated scale; or (*b*) the jet may be made to play for such time as will cause a definite opacity and the time required compared with a calibrated time scale. This method is suggested for discussion and has not been used.

6. A measured volume of air may be drawn through filter paper and the degree of discoloration produced on the paper measured or compared with calibrated papers. This method has been tried in Glasgow with considerable success, but it would seem to give results which depend somewhat on the colour of the matter caught as well as its amount.

7. An optical method might be used by which the opacity, to a standard light, of a column of air of given length is measured. This could probably be arranged to give the quantitative amount of impurity present by preparing a scale of opacity from measurements taken on air with known amounts of suspended matter present.

8. Rain might be caught and its opacity compared with a standard scale made by adding definite quantities of soot to distilled water. This method, or a somewhat similar one, was used by Dr. Fritzsch for measuring smoke in chimneys. (See Donkin in 'Engineer,' May 26, 1899.) The method is open to the same objection as No 2, also its results would depend on the nature of the impurity as well as the quantity present.

9. Boxes may be exposed having a collecting surface of one square foot and the contents collected and analysed. Such boxes were devised by Mr. Peter Fyfe, Chief Sanitary Officer, Glasgow, and exposed in that city in prominent positions. The method is a simplified form of No. 2.

7. *Temperature Frequency Curves.* *By* E. Gold, *M.A., and* F. J. Whipple, *M.A.*

8. *The Lunar Influence on Terrestrial Magnetism, and its Dependence on Solar Periodicity. By* Sydney Chapman, *D.Sc.*

9. *The Distribution of Large Earthquakes in Space and Time.*
By Rev. H. V. Gill, *S.J.*

In this paper the author adduced further evidence in favour of the theory he proposed some years ago: that under certain conditions earthquakes taking place at a given locality may occasion seismic and other disturbances at other places symmetrically situated round the earth's circumference. This theory was accepted by the late Dr. Milne. The present paper was based on the analysis of almost a thousand earthquakes which Milne had tabulated with regard to their occurrence in time and space, and which was only completed last year. The writer deduced from this catalogue the interesting fact that nearly 20 per cent. of large earthquakes takes place in groups of two or more within a few days of each other, occurring at distant places symmetrically situated. He explained why, from the principle on which he bases this theory, the number of such groups is not greater. He finds that these earthquakes may be divided into three general categories .—

(1) Groups in which the different earthquakes take place within a short interval of each other in distant places symmetrically situated (18·6 per cent.)[1]; (2) groups in which the different disturbances take place within a short interval of each other in or near the same locality (57·1 per cent.); (3) individual earthquakes having no connection in time or space with other disturbances (24·3 per cent.). It was pointed out that these three classes of disturbance are to be expected as the result of the general strain set up in the earth, treated as a rotating body, owing to the mass-displacements which tend to cause a deflection of the earth's axis. The deflection itself may be small, but the effect produced may easily be sufficiently great to occasion a seismic disturbance which, owing to other causes, is on the point of manifesting itself.

The accompanying table represents the result of the analysis of the earthquakes marked on the British Association chart.

The first column indicates the year. The second gives the total number of earthquakes which were sufficiently great to be considered world-shaking, and which were registered at least over a hemisphere. Column I. gives the number of shocks which were members of groups of two or more occurring at distant places symmetrically located. Column II. gives the number of those which were members of groups occurring at or near the same place. Column III. gives the single disturbances unconnected with others, either as regards time or space:—

		I.		II.		III.	
Year.	Total No	Groups at different places.		Groups in same district.		Single shocks.	
			Per cent.		Per cent.		Per cent.
1899	69	13	18·8	39	56	17	24·6
1900	45	12	26·6	20·	44·4	13	29·0
1901	56	8	14·4	36	64·2	12	21·4
1902	67	18	26·8	42	63·2	7	10
1903	81	21	25·9	40	49·4	20	24·7
1904	67	10	15	37	55	20	30
1905	79	9	11·4	49	62	21	26·6
1906	120	23	19·2	64	53·3	33	27·5
1907	88	14	16	53	60	21	24
1908	89	12	13	51	57·4	26	29·2
1909	128	23	18	80	62·5	25	19·5
Total	889	163		511		215	
Mean per ann.	80·81	14·6	18·6	46·4	57·09	19·54	24·2

[1] These numbers give the mean values for the whole period of eleven years. It is important to note that there is, on the whole, a very good agreement between the mean value and the values for the individual years, indicating that the distribution of earthquakes in time and space is according to some such law.

10. *Notes on the Construction of Seismometers.* *By* Rev. W. O'Leary, *S.J.*

Tremor Storms.—The minute and long-continued disturbance of the seismometer called the 'tremor storm' is a troublesome and to some extent a perplexing phenomenon. Tremors due to high wind have an irregular period that is unmistakable. The causes of tremor storms of uniform period are not quite understood. At Limerick such movement often develops during high wind, frequently attaining its maximum when the wind has fallen, and continuing for several days after. The period of the vibration varies from about 5·5 seconds towards the end of winter to 15 or 20 seconds in summer. There is little doubt that at Limerick many of these 'tremor storms' are due to high seas on our west coasts. It would be interesting if the same cause could be recognised at other stations.

Convection air currents are probably accountable for a good deal of trouble in other cases. A simple experiment shows how easily such currents may be produced. Very light rods of straw or wood are suspended in corked bottles from silk fibre. If a group of such bottles be placed in a room of even very uniform temperature, *e.g.*, a cellar, the rods are soon observed to all point in the same direction. Lighting a jet of gas 10 or 12 feet away will gradually turn them all towards the gas jet. The effect is evidently due to heat convection currents. By using large flat dishes instead of the bottles we can choke down convection effects, and under these conditions the rods show no definite set. A delicately balanced seismometer should readily respond to such currents if its mass is small. Hence it would seem advisable to raise the mass of light photographic recorders.

Photographic registration, though frictionless, is unsatisfactory. High magnification of the preliminary tremors is essential to analyse the shock and determine its epicentre. The maximum phase is then generally lost, owing to the rapid movement of the light spot. On the other hand, a large increase of mass renders the friction factor in mechanical registration very small; it is easily calculated, and the record is complete.

Ink Registration.—The ordinary method of mechanical registration by smoked paper is very sensitive, but has serious defects. The writer uses ink registration. The mass required is greater, but the perfection of the record outbalances the objection. Large masses, too, are perhaps easier to work with than small masses.

The vertical component instrument is essential to a first-class station, but many have found it mechanically unsatisfactory. Slight temperature changes alter the elasticity of the balancing spring. To avoid 'pen wandering' a temperature compensator on the gridiron principle is generally employed. The writer suggests prevention rather than cure. The spring, instead of being placed above the lever arm in the air, might be placed below it in an oil tank sunk deep in the concrete pier. If, in addition, a layer of non-conducting substance surrounds the tank, the spring should remain at a practically constant temperature.

Department of Mathematics.

1. *Direct Derivation of the Complementary Theorem.* *By* Professor J. C. Fields, *F.R.S.*

2. *Symmetric Linear Substitutions.* *By* Professor H. Hilton.

3. *On the Divisibility of* (2^p-2) *by* p^2. *By* Lieut.-Colonel Allan Cunningham, *R.E.*

Up to the present time it has been supposed that $2^p-2=0$ (mod p^2) is *impossible*. And it has been affirmed impossible by some writers (notably by M. Pratt). This had been tested up to $p \not> 1000$ by the present writer, and has been confirmed by

several writers. But Herr Waldemar Meissner, of Charlottenburg, has recently found that it *is possible* when $p=1093$, and for no other prime up to $p \ngtr 2000$.

As it has been shown (by Herr Wieferich) that the possibility of Fermat's Last Theorem $x^p+y^p=z^p$ required the possibility of $2^p-2=0 \pmod{p^2}$, one difficulty in the way of Fermat's Last Theorem has now been removed.

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4. *An Electromagnetic Theory of the Origin of Series Spectra. By* Professor A. W. Conway.

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5. *On Map-colouring. By* Professor A. C. Dixon, *F.R.S.*

If the surface of a globe (or a plane surface) is divided into provinces in any way, then by the use of four colours only, say, 1, 2, 3, 4, the provinces can be so coloured that no two which adjoin each other along a line are coloured alike. (This theorem is, I believe, as yet unproved.)

Let a line in the figure be marked a when it separates two provinces coloured 2 and 3 or 1 and 4, b when it separates 31 or 24, c when it separates 12 or 34. Then the problem of colouring the map is equivalent to that of lettering the lines, so that at any 'vertex' where three lines meet the three lines are differently lettered. (It may be assumed that not more than three lines meet at any vertex.)

Let a vertex be marked + when a rotation in the positive direction about it leads from the a line to the b line and then to the c line, and—when this order is reversed. Let $+1$ and -1 be called the 'affixes' of the vertex in the two cases. Then the problem of colouring the map is further reduced to that of assigning the signs or affixes of the respective vertices, and the only conditions to be satisfied are that in each province the sum of the affixes of the vertices shall be a multiple of three: the provinces are supposed simply connected.

These conditions are linear congruences to modulus 3. If there are p provinces and v vertices there are v affixes restricted by p relations of which only $p-1$ are independent, since the addition of all the congruences gives an identity.

Hence $v-p+1$ of the affixes may be chosen arbitrarily and the rest found linearly in terms of them so as to satisfy the congruences. It is necessary, however, that no affix so found should have the value zero, and to prove that this can always be secured does not appear to be any easier than to prove the original theorem.

The left sides of the congruences satisfy the following conditions:—

(1) Each unknown occurs in exactly three of the congruences, its coefficient being $+1$ in each case.

(2) The number of unknowns common to any two congruences is two or zero. (This excludes maps in which the same two provinces have two or more sides common. Such maps are easily reduced to simple ones.)

Conversely, a set of linear expressions satisfying the conditions (1) (2) correspond to a certain definite map, drawn on a sphere or on a multiply connected surface or surfaces as the case may be.

Since the theorem of the four colours is not true for maps on a multiply connected surface it must be impossible to deduce it from the mere general form of the congruences.

The reduction from the four colours 1, 2, 3, 4, to the three kinds of line a, b, c, and thence to the two affixes ± 1, is curiously analogous to the process of solving a quartic equation by means of a cubic, which itself is solved by means of a quadratic.

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6. *On a certain Division of the Plane. By* Professor A. C. Dixon, *F.R.S.*

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7. *A Development of the Theory of Errors with reference to Economy of Times. By* M. D. Hersey.

An enumeration of the results to which we are led in studying the problems of *design* and of *computation* is followed by a detailed consideration of the problems of *observation*.

In connection with the problem of *designing* (or adjusting) apparatus so as

to secure the most favourable result in a limited time, a criterion for 'best magnitudes,' previously proposed,[1] is here further considered, and illustrated by an application to the interferometer.

In regard to *computation*, the availability of an automatic device for linear least-square adjustment[2] makes it now desirable to have some means of throwing an assumed relation into linear form without disturbing the relative weights of the observations. A general formula for doing this is here proposed, and applied to the determination of thermal expansion coefficients.

Finally, the investigation of economy of time in taking the *observations* themselves leads to two distinct problems: first, that of the division of time amongst the components of an indirect measurement; second, that of the best grouping of observations in determining any one quantity.

The solution of the first problem comes out in terms of three data—namely, the relative precision of, and the relative time consumed in, a single observation on the respective components; together with the derivatives expressing the sensitiveness of the result with respect to the several components. Of these data the first two are postulated, while the third is implicitly contained in the equation which defines the measurement in question. The solution is independent of the existence of constant errors.

The second problem consists in establishing the most profitable compromise between the extremes of (1) repeating a large number of readings under the same conditions (or on the same sample), in order to diminish the effect of *observational* errors; or (2) resting content with a lower precision on each determination, in order to cut down *systematic* errors by making numerous independent determinations (or by trying many different samples). The most economical number of observations to make in any one group before stopping to change conditions (or to set up a new sample) in preparation for a new group is directly expressible in terms of two postulated data. There are, first, the ratio of the average observational error to the average systematic error anticipated; and, second, the ratio of the time required in preparing for a new group to the time used in a single observation. This result is independent of the total time available.

The first problem is illustrated by the division of time in a gravity determination by Kater's pendulum; the second, by the determination of the heat of combustion of coal from a series of samples.

A combination of the two problems may also arise. The solution is equally straightforward.

Throughout, the object of the paper has been to establish certain *general* principles governing the accuracy attainable in physical measurements, independently of the *particular* apparatus or process in question.

8. *Some Remarks on Waring's Problem.* *By* Professor J. E. A. Steggall.

9. *On a System of Spherical or Hyperspherical Co-ordinates.* *By* T. C. Lewis.

If any hypersphere be taken, let the co-ordinate of a point with reference to it be $\frac{S}{\rho}$, where ρ is the radius and S the square of the tangent from the point considered. In n-space take any system of $n+2$ fundamental spheres such that each one cuts all the others orthogonally. Their centres are at the vertices and orthocentre of an orthocentric figure.

Let the co-ordinates of a point be $x_1, x_2 \ldots, x_{n+2}$.

They are connected by the two relations:—

$$\Sigma \frac{x_\kappa}{\rho_\kappa} = -2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (i)$$

$$\Sigma x_\kappa^2 = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (ii)$$

[1] *Jour. Wash. Acad. Sci.*, vol. i., 1911, p. 187.
[2] *Ibid.*, vol. iii., 1913, p. 296.

The equation of any n-hypersphere is homogeneous of the first degree, viz. :—

$$x \equiv a_1 x_1 + a_2 x_2 + \ldots \quad a_{n+2} x_{n+2} = 0,$$

where a_κ is the cosine of the angle at which this hypersphere intersects the Kth fundamental hypersphere.

The radius ρ is given by the formula

$$\frac{1}{\rho} = \Sigma \frac{a_\kappa}{\rho_\kappa}.$$

The co-ordinates of the centre are given by

$$x_\kappa = \frac{\rho(\rho - 2a_\kappa \rho_\kappa)}{\rho_\kappa}.$$

Thus

$$\Sigma_1^{n+1} \rho^\kappa x_\kappa = (n - 2r - 1) \rho_{n+2} x_{n+2}$$

represents an n-sphere which intersects every r-face of the figure, whose vertices are the first $n+1$ of the fundamental points, in a section whose diameter is the line joining the orthocentre and centroid of that face. The radius ρ_r is given by

$$4(r+1)^2 \rho_r^2 = \Sigma_1^{n+1} \rho_\kappa^2 + (n - 2r - 1)^2 \rho_{n+2}^2.$$

The centre, O_r, for all values of r, lies on the line joining O, the circumcentre, to P, the orthocentre, so that

$$PO_r = PO / r + 1.$$

If $2r = n$, the equation becomes symmetrical with respect to all the fundamental spheres, and gives the complete analogue to the nine-point circle of plane geometry.

The homogeneous equation of the second degree is in general that of a locus analogous to bicircular quartics, or to cyclides, reducible to analogues of conic sections or conicoids.

TUESDAY, SEPTEMBER 16.

Joint Meeting with Section E.—See p. 553.

DEPARTMENT OF GENERAL PHYSICS.

The following Papers were read :—

1. *The Electric Arc as a Standard of Light.* *By* J. F. FORREST.

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2. *Some Experiments in Contacts between Electrical Conductors.* *By* DR. W. H. ECCLES.

When a current is passed across a 'loose contact' the relation between the applied electromotive force and the current produced is, in general, not a linear one, and no sufficient explanation of the observed phenomena has hitherto been offered. The present author investigates whether the behaviour of contacts can be accounted for by purely thermal actions in the matter near the contact. The Joule, the Peltier, and the Thomson effects will all play a part, and the alterations of resistivity with temperature, as well as alterations of the geometrical configuration of the surfaces in contact caused by thermal expansion, ought all to be taken into account. These thermal effects are, of course, most noticeable in contacts between bad conductors of electricity and of heat, as, *e.g.*, the natural crystalline oxides and sulphides.

It is advantageous to separate contacts into two classes: First, those between like substances; second, those between unlike substances. In the first class there is in general no thermoelectric action, and the non-linearity of the relation

between applied e.m.f. and current is mainly due to resistivity changes produced by Joulean heating. In the second class there is in general some thermoelectric action imposed on the resistivity-temperature phenomenon; and in the case of the crystalline substances mentioned the thermoelectric actions may be the more important.

For the first class, theory yields a cubic equation connecting e.m.f. and current. Experiments are adduced by the author which show that the thermal explanation is in many cases sufficient. In the second class, thermoelectric theory yields a quantic equation. The curve connecting e.m.f. and current takes very various shapes according to the signs and the relative magnitudes of the Peltier and Thomson coefficients in the substances forming the contact. The author has measured these coefficients in some typical substances and has thus carried out a comparison between the theoretical curves and the experimental curves of contacts between pairs of these substances. The evidence gathered in this way tends in the main to support the theory.

3. *The Twisting of India-rubber.* *By* Professor J. H. Poynting, *F.R.S.*

4. *The Resistance of Air to Falling Spheres.* *By* G. A. Shakespear, *D.Sc.*

The experiments described fall into two classes:—

(*a*) The determination of the time of fall of a hollow celluloid sphere of 3·70 cm. diameter through different distances, for a series of different weights of the sphere; the resistance being assumed to be equal to the weight in air of the sphere when the limiting velocity is attained; and

(*b*) The relation between the resistances for a series of spheres of different diameters (from 2·01 to 7·52 cm.) for a velocity of 1,030 cm./sec. In the formula $R = KSV^2$, where R = resistance in dynes, S the area of diametric circle of sphere in square cm., and V the velocity in cm./sec., the value of K ranged from 2·50 to $2{\cdot}66 \times 10^{-4}$ grms/cm.^{3} for the sphere of 3·70 cm. diameter when the velocities ranged from 850 cm./sec. to 1,320 cm./sec. For the different spheres at velocity of 1,030 cm./sec., the value of K ranged from $2{\cdot}85 \times 10^{-4}$ for that of 7·52 cm. to $2{\cdot}58 \times 10^{-4}$ for that of 2·01 cm. The value of K diminishes gradually with the diameter and with the velocity.

5. *A New Method of Starting Mercury Vapour Apparatus.*[1] *By* J. S. Anderson.

In the best types of mercury vapour lamps and rectifiers at present on the market, the arc is started by tilting the lamp or rectifier, either by hand or automatically. Now this tilting arrangement is very often inconvenient. This is found to be especially the case when one is dealing with lamps used for scientific purposes. For example, in carrying out experiments on the Zeeman effect a mercury vapour arc lamp is extremely suitable. But the difficulty arises from the fact that the lamp must be placed between the poles of an electro-magnet, the distance between the poles being usually so small that any tilting apparatus that may be employed interferes with the proper mounting of the lamp.

Mr. G. B. Burnside and the author have overcome this difficulty by constructing a lamp which may be fixed in position between the poles of an electro-magnet, or in any other suitable position, and then started without having to be tilted. This is brought about by the employment of a heating arrangement near one of the electrodes, preferably the negative electrode. The lamp tube is provided with a small vessel near this electrode, the vessel having a re-entrant

[1] John S. Anderson and George B. Burnside, *Proc. Roy. Soc. Edin.*, xxxiii. (1913), p. 117.

portion or recess in which a heating element is placed. The part of the tube immediately above this small vessel and its recess is constricted. The heating element may conveniently consist of a small coil of platinum wire wound round a suitable support; it may be placed in the recess of the small vessel or removed at will, without interfering with the vacuum of the lamp. The heating coil of wire is connected in series or in shunt, in the latter case being provided with an automatic cut-out. An external resistance is placed in series with the lamp. Before starting, the small vessel is full of mercury, which forms a continuous connection inside the tube between the positive and negative electrodes. When the electrical current is switched on, the heating coil becomes incandescent, and the heat given off by the wire goes to raising the temperature of the vessel and its contained mercury, there being no appreciable loss by radiation into the surrounding air. Very little heat is required, because the first bubble of mercury vapour formed rises to the constricted portion of the lamp and is there caught, thus breaking the continuity of the mercury inside the lamp and starting the arc. Owing to the resistance of the mercury vapour, which is formed once the arc is started, the current is cut down to the value required for running the lamp. The platinum wire of the heating element can be made of such a thickness, and the external resistance can be so adjusted, that the wire does not emit heat when the lamp is working, but becomes incandescent when the lamp is started, the action being quite automatic.

6. *The Transmission of X-rays through Metals.* *By* H. B. Keene.

A photographic examination of secondary Röntgen radiation leads to results of a different nature from those obtained by the ionisation method. When a narrow cylindrical pencil of X-rays is made to pass normally through thin rolled metal sheets, and fall upon a photographic plate placed behind and parallel to the sheet, some curious patterns are obtained.

These patterns fall into two classes: (*a*) in which the central spot produced by the direct beam is surrounded by an irregular halo of smaller spots, and (*b*) in which the central spot is surrounded by faint extended patches forming a *perfectly symmetrical pattern.* The design varies with the metal.

Class (*a*) markings are given by metal sheets which have been annealed, while the symmetrical patterns of class (*b*) are only obtained with newly rolled sheets which have not been annealed. It appears that the spots of the former are due to reflections from the microcrystals within the metal, while the symmetrical patterns of the latter are produced by the structure imparted to the metal in passing through the rolls.

These star-like patterns are evidently analogous to those obtained when a beam of light passes through a crystal which appears streaky to the naked eye, the striations acting as a diffraction grating. (H. S. Allen, *Nature*, 91, p. 268.)

7. X_3 *and the Evolution of Helium.* *By* Sir J. J. Thomson, *O.M., F.R.S.*

8. *A New Elementary Constituent of the Atmosphere.* *By* F. W. Aston.

Sir J. J. Thomson has recently called attention to some results obtained with the method of positive rays which imply the probable existence of an element of atomic weight about 22.

This point has been further investigated, and evidence has now been obtained that atmospheric neon is not homogeneous, but consists of a mixture of two elements of approximate atomic weights, 19·9 and 22·1 respectively.

Partial separation has been effected by fractional diffusion attested by a change of density, the latter being determined by a new and simple method.

The two elements appear to be identical in all their properties except atomic weight. No change in the spectrum corresponding to the change of density has been observed.

9. *The Minimum Quantity of Light discoverable by means of Selenium.* *By* Dr. E. E. Fournier d'Albe.

This paper dealt with the behaviour of selenium under very faint illuminations. The changes in conductivity resemble phenomena of ionisation and recombination, inasmuch as the light-action curve satisfies the equation $dK/dt = I - CK^2$, where I is the illumination, C the coefficient of recovery on recombination, and K the additional conductivity imparted to selenium by the action of light. The initial light-action is a linear function of the time, so that the action observable in a given time is proportional to the 'exposure' if the latter is short. The final additional conductivity is proportional to the square root of the illumination. This offers a means of discovering very faint illuminations. A current of the order of 10^{-9} ampère is obtainable by the unaided illumination produced by Venus, and it should be possible to discover invisible stars by means of a sensitive galvanometer without any optical aid. Attempts to do this were described, and the bearing of the results on the theory of quanta was discussed.

(Some new applications of the properties of selenium were demonstrated at the University buildings.)

10. *Discussion on Professor W. H. Bragg's Paper on Crystals and X-Rays.*

11. *A New Process for Enlarging Photographs.* *By* A. J. Lotka.

12. *A Magnetic Susceptibility Meter.* *By* W. H. F. Murdoch.

The author uses a unipolar method of testing, with the addition of a circular coil in series with the magnetising solenoid. This coil acts upon the magnetometer needle which is lying in a neutral field of force, so that the tangent of the resulting deflection due to the magnetic material plus coil is strictly proportional to magnetic susceptibility.

A mirror may be used to read the deflections, and in this case susceptibility = deflection × constant.

It follows that such an instrument with tangent scale and pointer can be graduated so as to read directly the value of the susceptibility coefficient in C.G.S. units. To fix the value of H the current is measured and the values multiplied by a constant.

The theory of the instrument was given, and an example of its use for testing iron, together with a diagram of connections and curve of results.

The various corrections were also briefly discussed.

13. *The Sensitiveness of the Human Skin as a Detector of Low Voltage Alternating E.M.F.*[1] *By* Professor H. Stansfield, *D.Sc.*

An alternating difference of potential of 40 volts, with a frequency of 50 cycles per second, between a piece of metal and the human body, is sufficient to produce a vibration which can be felt when the back of the hand is lightly rubbed against the metal. If the metal is connected to a live wire, the observer should be well insulated from the earth.

The alternating E.M.F. acting across the thin badly-conducting surface layer of the skin produces a rapid variation of the frictional force. If the metal is allowed to rub against the ear, instead of the hand, the vibration is heard as a musical note.

The human skin may be imitated for this purpose by gilding a rounded lump of jelly with gold leaf and then covering it with a piece of thin silk. The imitation is not, however, as sensitive as the original.

[1] Printed in full in the *Electrician*, September 26, 1913.

14. *A Method of Increasing the Sensitiveness of certain Measuring Instruments.* *By* G. A. Shakespear, *D.Sc.*

Any instrument the indication of which is made by the reflection of a beam of light from a mirror can be made more sensitive by allowing the mirror to reflect the image of a powerful source of radiation (*e.g.*, a Nernst filament) on to the receiving vane of a radiomicrometer or other measurer of radiant energy. If the primary instrument be a galvanometer the movement of the image through 1 mm. may produce a movement of the beam from the radiomicrometer through 1,000 mm., thus increasing the movement observed 1,000 times. The beam from the secondary instrument may be allowed to fall on a tertiary one with a further magnification of a like order. In this way exceedingly minute rotations of the mirror of the primary instrument can be detected. The name 'microtropometer' is suggested for such a combination of instruments.

WEDNESDAY, SEPTEMBER 17.

The following Reports and Papers were read :—

1. *Report of the Seismological Committee.*—See Reports, p. 45.

2. *Report on the Investigation of the Upper Atmosphere.*—See Reports, p. 130.

3. *Report on the Further Tabulation of Bessel and other Functions.*—See Reports, p. 87.

4. *Report of the Committee to aid in Establishing a Solar Physics Observatory in Australia.*—See Reports, p. 132.

5. *Report of the Committee on Radiotelegraphic Investigations.*—See Reports, p. 131.

6. *Report of the Committee on Electrical Standards.*—See Reports, p. 133.

7. *Report on the International Tables of Physical and Chemical Constants.*

8. *A New Method of Sealing Electrical Conductors through Glass.* *By* M. J. Anderson.

While experimenting with a new method of starting mercury vapour apparatus[1] Mr. G. B. Burnside and the author experienced great difficulty at first in obtaining a satisfactory method of sealing the electrical conductors through the glass of the lamps with which the experiments were carried out.

[1] *Proc. Roy. Soc. Edin.*, xxxiii. (1913), p. 117.

Mr. Burnside, however, solved the difficulty by devising a simple method [3] whereby platinum wires may be sealed through Jena glass; according to the same method other conductors, such as copper wires, may be sealed through ordinary glass.

The method consists essentially in fusing the metal and glass together in the usual way and then immersing the seal, after it has cooled to about a red heat, in a bath of oil or fat. Each immersion lasts about two or three seconds. The seal is immersed a little further in the cooling medium at each successive immersion until it is completely cooled.

For currents up to 15 ampères solid conductors may be employed, but for larger currents it is found advisable to make use of tubular conductors, which may be quite easily sealed through glass according to Mr. Burnside's method.

In preliminary experiments copper wires 1.5 mm. in diameter were successfully sealed through German glass, and platinum wires of 1 mm. diameter were sealed through Jena and other glasses. A copper tube, capable of carrying a current of 100 ampères, was sealed through German glass. Platinum wires were sealed through Jena glass in mercury vapour lamps, and the seals were found to be air-tight after a period of over eight months, although they had from time to time been subjected to the heat of the lamps when burning.

The chief advantages of this method of sealing electrical conductors through glass are as follows: (1) The process of obtaining seals is much simpler than any at present in use; (2) for incandescent electric lamps and all kinds of vacuum tubes, with the exception of mercury vapour apparatus, copper or other high conductivity metal may be used as the conducting material; (3) in the case of mercury vapour apparatus a minimum quantity of platinum is used in the tubular form of conductor for large electrical currents, because the tubular shell may be filled in with copper, subsequent to the sealing process; (4) conductors of very much greater cross-section than it has hitherto been possible to employ may be sealed through glass; (5) the one process is applicable to all kinds of glasses.

9. *Exhibition of a Seismograph.* *By* J. J. SHAW.

10. *A Simple Method of determining the Period of Waves at Sea.* *By* DR. VAUGHAN CORNISH.

Hitherto the method of determining the period of waves at sea from a ship on her course has been to note the interval between the arrival of waves at the bow or stern of the vessel, and the angle which the direction of their advance makes with the ship's course. The speed of the ship being known, the true period can be calculated.

During a voyage from Southampton to Colon and back in 1912 the author found that the true period of the waves can be quickly and accurately determined from the vertical oscillations of patches of spent foam, which are always numerous upon the surface of the sea except during absolute calm. With the aid of a stop-watch the interval is taken between the times when a patch of foam is borne upon the crest of successive waves. By this means it is not difficult to determine the period of the swell as well as that of the waves which are driven by the wind which blows at the time of observation. The post of observation should be as high as possible above the water in order to discriminate more clearly between the shorter, steeper waves and the longer, flatter swell.

The method is not only quicker than that hitherto in use, but has the important advantage that it obviates the necessity for observing the direction of advance of the waves, which is difficult to determine with accuracy.

The following are examples of the measurements made by the author :—

May 28, 1912, average period of 28 waves, 2·095 secs.,
May 28, 1912, average period of 25 waves, 2·156 secs.,

the two sets being taken one immediately after the other.

[3] *The Electrician*, July 4, 1913.

May 26, 1913, period of swell, average of 10, on starboard = 10·6 secs.
May 26, 1913, period of swell, average of 10, on port = 10.3 secs.
May 22, 1912 (in a steady N.E. trade wind):
At 11.30 A.M., swell 7·4 secs., waves 3·55 secs.
At 3.30 P.M., swell 7·5 secs., waves 3·25 secs.

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11. *The Dynamics of Evolution.* By A. J. LOTKA.

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12. *Microscopic Crystals, with Epidiascope Illustrations* By G. HOOKHAM.

13. *The Goldschmidt Dynamo.* By Professor T. R. LYLE, *F.R.S.*

SECTION B.—CHEMISTRY.

PRESIDENT OF THE SECTION:

PROFESSOR W. P. WYNNE, D.Sc., F.R.S.

THURSDAY, SEPTEMBER 11.

The President delivered the following Address:—

WHEN the present position of education in Birmingham is considered, the transformation effected since the 'seventies is little short of marvellous. Five-and-thirty years ago, when I became an evening student, classes conducted by the Midland Institute met the demand for Arts and Science subjects; now a University—venerable in comparison with all Civic Universities save the Victoria University of Manchester—exists to provide instruction in every branch of learning. The spacious building in which we meet—already too small for the demands made on it—is the lineal descendant of that part of the Midland Institute which formerly was used for evening class instruction in science, organised in connection with the Science and Art Department, and financed largely by the system of payment on results; this large lecture theatre replaces the small and inconvenient classroom in which the teaching of Chemistry and Physics under Mr. Woodward was carried on. Payment on results is obsolete, and the 'May' examinations on which it was based have almost disappeared, assessment by inspection now replacing both; nevertheless, it is more than doubtful whether any other system—in the circumstances of the time—could have spread so widely a knowledge of science among the people, or prepared the way for the Technical Instruction Act, and that appreciation of the value of scientific training for industrial pursuits which is exemplified by the provision through municipal agencies of Technical Schools in the industrial centres of this country. I sometimes think the Science and Art Department, and those great men, Sir John Donnelly and Professor Huxley, who did much to shape its attitude towards science instruction in evening classes and in the Science Schools at South Kensington,[1] have received something less than their share of credit for pioneering work which finds its fruition in well-equipped Institutions like this, and in the enhanced position which science holds to-day in the estimation of our countrymen. In those far-off times, before the foundation-stone of Mason College was laid, such evening classes in Birmingham provided the only means by which instruction in science, or scholarships to South Kensington, could be obtained. It is not unfitting, therefore, that I—a product of the system—should acknowledge here the obligation

[1] These Schools in 1881 became the Normal School of Science, and in 1900 the Royal College of Science, now incorporated in the Imperial College of Science and Technology.

under which I stand both to the Midland Institute and to the Science and Art Department for providing the ladder by which I have risen, however undeservedly, to the honourable position of President of this Section.

The historian of our times will not fail to note some of the consequences which have followed the application of science to industry, possibly also some of the educational results which have followed the development of science teaching in schools of all grades. Except from one point of view these need not concern us now, as they fall, the one in so far as Chemistry is concerned, into the province of the Society of Chemical Industry, the other mainly within the purview of Section L. This bringing of Chemistry to the people has aroused a widespread interest in some aspects of the subject, of which the Press has not been slow to take note. Not even the heuristic method can hide from the schoolboy the fact that certain fundamental conceptions are accepted which do not admit of proof, such as the indivisible atom, the non-decomposable element, the indestructibility of matter. When, therefore, as one of the first-fruits of his discovery that positive rays furnish the most delicate method of chemical analysis, Sir J. J. Thomson has obtained from the most diverse solids a new gas, X_3; and by a different procedure, Professor Collie with Mr. Patterson have discovered that hydrogen, under the influence of electric discharges at low pressure, becomes replaced by neon, helium, and a third gas which is possibly identical with X_3,[2] it is not surprising that we should hear much about it in the newspapers, just as was the case when the disintegration of radium was in process of being established. Further investigation may fail to substantiate some of the views which have been expressed about this unexplained disappearance of hydrogen; the origin of the neon and helium which make their appearance in the tube as the experiments proceed; the source of the gas X_3. Fortunately X_3, unlike neon and helium, has some chemical properties—it disappears, for example, when violently exploded with a mixture of oxygen and hydrogen—but we do not yet know whether it is a new element with an atomic weight of about 3, or a compound of hydrogen with an element yet to be discovered. This much at least seems certain; it is not the gas which, according to Mendeléef, should precede fluorine in the halogen series, but whether its discovery, like that of argon, will necessitate a revision of the Periodic table of the elements we cannot know until the mystery which at present surrounds it has been dispelled.

It was in 1886, at the last meeting of this Association in Birmingham, that Sir William Crookes whose continued activities are a source of pride and gratification to his brother chemists—gave that famous address in which, clothing his ideas in language which has something of the magic of word-painting, he traced the evolution of the elements, as we know them, from the hypothetical protyle or Urstoff. The common origin of all elementary substances is now an accepted theory, although the question whether the idea underlying the term 'transmutation' is verifiable under available conditions is answered differently according to the view we take of the disintegration of radium and kindred phenomena. But no one could have imagined that before another Birmingham meeting, the Periodic table to which Sir William Crookes devoted much attention would have been enriched not only by a series of elements devoid of chemical properties, but by a second series, known only in minute quantities, and displaying those extraordinary properties of radio-activity which have revolutionised our ideas in more than one direction.

It is not necessary for me to chronicle even the more striking achievements in chemistry since 1886; a few examples will show how great the progress has been. It is on record that Arrhenius was present at that meeting, but his advocacy of that theory of solution with which his name will always be associated came a little later; phenylhydrazine, which was to play so important a part in Emil Fischer's investigation of the sugars, had been discovered by him only two years previously; the Grignard reagent, which in other directions has played a no less important part in synthetical organic chemistry, did not become available until some fourteen years later. Theories then emerging, such as that

[2] J. N. Collie and H. S. Patterson, *Trans. Chem. Soc.*, 1913, **103**, 419; *Proc. Chem. Soc.*, 1913, **29**, 217.

[3] Sir J. J. Thomson, *Proc. Roy. Soc.*, 1913, **89A**, 20.

of geometrical isomerism, have either been discarded or modified by the discovery of new facts, and who shall say that the theory of ionic dissociation stands where it did, now that ions in solution have incurred the suspicion of associating with the solvent, and to that extent have come into line with molecules, for the orthodox behaviour of which Professor Armstrong himself would no doubt be prepared to vouch?

Residual Valency.

Among the many doctrines which have suffered under the stress of long-sustained investigation, that of valency is a prominent example. Valency is that property by which an atom attracts to itself other atoms or radicals, and its numerical value is deduced from the structural formulæ of compounds in which that atom occurs. Claus seems to have been the first to recognise that this attraction between two atoms is not a constant, but depends on the nature of the other atoms or radicals in the molecule,[4] and it is of interest to note in connection with what follows that he used methane and its chloro-derivatives to illustrate his point of view. Valency may vary, therefore, from compound to compound; it is known to alter under the influence of change in temperature, as, for example, when carbon dioxide or phosphorus pentachloride undergoes thermal dissociation. But Claus' view did not meet with ready acceptance; hence at the Birmingham meeting few chemists, if any, would have questioned the quadrivalency of carbon, despite the difficulty caused by the existence of carbon monoxide. Now, carbon is believed to be bivalent in the carbamines, fulminic acid and other compounds as well as in carbon monoxide, and its tervalency is coming to be accepted in the light of the latest investigations on triphenylmethyl and its congeners. What is true of carbon is equally true of all other elements, except argon and its companions. Hence the doctrine of constant valency for which Kekulé contended, or that of variable valency in which the uncombined units varied by even numbers has necessarily given place to one of less rigid type, although the final form has yet to be determined.

For the purpose of this address it will be sufficient to refer only to one of these later theories: that in which Werner, as the outcome of his exhaustive study of inorganic molecular compounds, and especially of the amines, supposes that an atom may have both principal and auxiliary or residual valency.[5] There are difficulties in its application to certain problems of organic chemistry—for example, the structure of the benzene molecule—but the conspicuous success which has attended Werner's investigation of the complicated isomerism of the cobalt and chromium amines is evidence of its value as a guide in stimulating research in the most unpromising directions.[6] Werner's view that valency is an attractive force acting from the centre of the atom, being of equal value at all points on the surface and independent of units of affinity, has the merit of meeting the objection long urged to the idea that affinity has fixed direction in space, but otherwise leaves untouched Van't Hoff's brilliant conception of asymmetry which plays so great a part in the chemistry of to-day.

What light does this conception of residual valency, dating back to 1885, if not earlier,[7] and now embodied in many theories besides Werner's, throw on some of the problems with which the organic chemist is faced? Much every way. The question of the distribution of valency in the molecules of carbon compounds is discussed probably more than any other; it arises in connection with the structure of unsaturated compounds, the properties of fluorescence or colour which many of them exhibit, and the relation between chemical consti-

[4] A. Claus, *Ber.*, 1881, **14**, 435. It may be noted that Claus concludes his paper with the statement, '. . . . die Annahme von Valenzen, als in den mehrwerthigen Atomen präexistirender ihrer Wirkungsgrösse nach bestimmter Anziehungseinheiten eine ebenso unbegründete, wie unnatürliche Hypothese ist.'

[5] A. Werner, *Neuere Anschauungen auf dem Gebiete der anorganischen Chemie* (Friedr. Vieweg u. Sohn, Braunschweig, 1908); English edition. *New Ideas on Inorganic Chemistry.* E. P. Hedley. (Longmans, 1911.)

[6] A. Werner, *Ber.*, 1911, **44**, 2445, 3231.

[7] S. U. Pickering, *Proc. Chem. Soc.*, 1885, **1**, 122; H. E. Armstrong, *Proc. Roy. Soc.*, 1886, **40**, 285.

tution and physical properties, to the elucidation of which an increasing amount of research is being directed. The double linkings in our formulæ no longer represent two units of valency in terms of hydrogen, nor are they now used to indicate polarity of the central atom or distribution of the valency in space; Werner's conception of valency accounts, as the phrase goes, for the concentration of re-activity at that part of the molecule where unsaturation exists, and it is of service when different degrees of unsaturatedness are displayed by compounds which, on the older view, would be expected to show similarity in chemical behaviour.[1] With your permission I propose briefly to review our knowledge of that type of chemical change known as substitution from the standpoint of residual valency.

Substitution in the Paraffin Series.

So far back as 1839 the fact was discovered that replacement of hydrogen by chlorine in the acetic acid molecule does not lead to any essential modification in the properties of the acid. It is not a little remarkable, therefore, that although much of the progress in organic chemistry has been achieved by substitutions of the most diverse types, we are still unable to say that agreement has been reached with regard to the nature of the processes by which this replacement of one radical by another in a molecule is brought about. Never has attention been concentrated more closely than now on the study of what, for want of a better phrase, is termed the 'mechanism of chemical reactions'—the processes which are covered and hidden by the sign of equality used, inaptly, in chemical equations—but the integrating mind, to the need for which Professor Frankland alluded on a recent occasion,[2] has not yet been evolved to reconcile the uncertain or contradictory answers vouchsafed to much patient experimenting. Organic chemistry is not singular in this respect: as much might be said about controversies not yet settled which concern themselves with such every-day phenomena as the chemistry of the candle-flame or of the rusting of iron.

It is a commonplace that Kekulé, to whom theoretical chemistry owes so many fruitful suggestions, was of the opinion that substitution is not a process in which what may be called a direct exchange of radicals occurs, but is preceded by the temporary union of the molecules of carbon compound and addendum, followed by disruption into two new molecules, the substituted carbon compound being one of them. It is clear, then, from the standpoint of Kekulé's hypothesis, that some degree of unsaturation is to be looked for in all carbon compounds and in all addenda. Hence, the paraffin hydrocarbons which furnish derivatives only by substitution, and, under the older, more rigid view of valency propounded by Kekulé himself, are typically saturated compounds, supply the exceptions to prove the general validity of the hypothesis that addition precedes substitution.

Before examining the case of these hydrocarbons, however, some advantage may be gained if the behaviour of other groups of compounds be examined in the light of the idea underlying Kekulé's view. By reference to the literature, it is evident that since the beginning of this century attention has been concentrated on the phenomena of substitution in the important group of carbonyl compounds, particularly the ketones and acids, which in many cases yield halogen substitution derivatives of one type. Thus methyl ethyl ketone when brominated in sunlight yields two bromoketobutanes of the constitution shown in

[1] As an example of the unsatisfactory character of the doubly linked formula to which the older meaning was attached, the following may be quoted: *unsym.*-Diphenyldichloroethylene, like ethylene, combines molecularly with bromine, but tetraphenylethylene does not;

$$\begin{array}{ccc} CH_2 & C(C_6H_5)_2 & C(C_6H_5)_2 \\ \| & \| & \| \\ CH_2 & C\,Cl_2 & C(C_6H_5)_2 \end{array}$$

yet a similar structure has been assigned to each (Biltz, *Annalen*, 1897, **296**, 219).

[2] P. F. Frankland, *Proc. Chem. Soc.*, 1913, **29**, 101.

the following formulæ, and propionic acid with bromine and red phosphorus under Volhard's conditions [10] gives α-bromopropionic acid,

$$CH_2Br{\cdot}CO{\cdot}CH_2{\cdot}CH_3 \text{ and } CH_3{\cdot}CO{\cdot}CHBr{\cdot}CH_3 \,^{11} \qquad CH_3{\cdot}CHBr{\cdot}CO{\cdot}OH$$

the halogen occupying what is termed the α-position with reference to the carbonyl radical. Why is substitution in the methyl group easier when this radical is present in acetone or acetic acid than it is in methane, is one question that may be asked. A second will inquire whether the carbonyl group has a directing influence, and, if so, by what means is it exercised.

It has been supposed by Werner that the distribution of valency is disturbed by the introduction of the oxygen atom of the carbonyl group into the molecule of the hydrocarbon; that this oxygen atom absorbs much of the valency of the carbon atom of the carbonyl group, leaving less to bind its neighbour or neighbours, which results in their having free valency, and thereby attaching substituents to themselves. This explanation, if accepted for the bromination of ketones and acids, also for the chlorination of ketones, does not account for the results recorded by Michael and by Montemartini in the case of carboxylic acids. Michael has found that the β-chloro-, not the α-chloro- acid is the chief product (60-65 p.c.) when homologues of acetic acid are chlorinated [12]; and Montemartini states that if the radical CH occur in any part of the carbon chain the exchange of hydrogen for chlorine takes place in that position, however distant it may be from the carbonyl group of the acid.[13]

$$\underset{\text{(Michael)}}{CH_3{\cdot}CH_2{\cdot}CHCl{\cdot}CH_2{\cdot}CO{\cdot}OH} \qquad \underset{\text{(Montemartini)}}{(CH_3)_2{>}CCl{\cdot}CH_2{\cdot}CH_2{\cdot}CO{\cdot}OH}$$

At present there seems to be no clue to the reason why chlorine and bromine in these reactions behave alike towards ketones and not towards acids.

An alternative explanation of this reaction, which has come to be widely accepted, is based on the remarkable property called desmotropy or dynamic isomerism, which certain of these carbonyl compounds exhibit. A desmotropic compound may exist in two or more forms, and its peculiar isomerism is known to depend on the mobility of a hydrogen atom in the complex $\cdot CH_2{\cdot}CO\cdot$ whereby an equilibrium is set up of the type:

$$\underset{\text{Ketonic form}}{\cdot CH_2{\cdot}CO\cdot} \rightleftharpoons \underset{\text{Enolic form}}{\cdot CH{:}C(OH)\cdot}$$

Of these two forms, the enolic is the more unsaturated, and presumably the more reactive.[14] Lapworth, making use of this desmotropic relationship, supposes that when the ketone reacts with halogen in dilute aqueous solution three changes

[10] J. Volhard, *Annalen*, 1887, **242**, 141; *Ber.*, 1888, **21**, 1904.

[11] L. Van Raymenant, *Bull. Acad. roy. Belg.*, 1900, 724. For the chloroketobutanes, *cf. idem*; Kling, *Compt. rend.* 1905, **140**, 312; *Bull. Soc. chim.*, 1905 [iii.], **33**, 322.

[12] A. Michael, *Ber.*, 1901, **34**, 4035, 4046.

[13] C. Montemartini, *Gazz. chim. ital.*, 1897, **27** [ii.], 368; 1898, **28** [ii.], 290.

[14] It may be of interest to note that the long controversy respecting the composition of ordinary ethyl acetoacetate $CH_3{\cdot}CO{\cdot}CH_2{\cdot}CO{\cdot}OEt$, the first of these desmotropic compounds to be discovered, has been brought to an end by the isolation of each desmotropic form at temperatures sufficiently low to inhibit the desmotropic change. From refractometric observations with mixtures of the pure isomerides, Knorr concludes that this ester at the ordinary temperature contains about two per cent. of the enolic form, whereas from bromination experiments with the ester itself, which may possibly be accompanied by a disturbance of the equilibrium, K. H. Meyer infers that the amount may be as much as seven per cent. (L. Knorr, O. Rothe, and H. Averbeck, *Ber.*, 1911, **44**, 1138; K. H. Meyer, *Annalen*, 1911, **380**, 222; K. H. Meyer and P. Kappelmeier, *Ber.*, 1911, **44**, 2718.)

occur which, for the case of acetone, may be represented by the following expressions :—

$$\begin{aligned}
&CH_3\cdot CO\cdot CH_3 &&\rightarrow CH_3\cdot C(OH):CH_2\\
&CH_3\cdot C(OH):CH_2 + Br_2 &&\rightarrow CH_3\cdot C(OH)Br\cdot CH_2Br\\
&CH_3\cdot C(OH)Br\cdot CH_2Br &&\rightarrow CH_3\cdot CO\cdot CH_2Br + HBr
\end{aligned}$$

the first being one of slow enolisation, accelerated catalytically by halogen acid, leading to the production of an unsaturated compound, which then by rapid addition of bromine and subsequent elimination of hydrogen bromide conforms with Kekulé's hypothesis. The intermediate compounds, it is true, have not been isolated, but a study of the dynamics of the reaction by Lapworth, and later by Dawson with his collaborators (using iodine instead of bromine), shows that this explanation is in harmony with the data obtained.[15] When the reaction is applied to carboxylic acids under similar conditions, the view that it takes a similar course finds support from an investigation of the dynamics of the bromination of malonic acid in aqueous solution.[16]

Whether evidence drawn from reactions found to take place in aqueous solution is relevant when bromination is effected by heating a carboxylic acid with bromine and red phosphorus may be doubted. Certainly it seems to afford no assistance in accounting for the course of chlorination in the acids examined by Michael and by Montemartini. Nevertheless, Aschan employs the keto-enolic hypothesis[17] to elucidate the results of a recent inquiry into the 'mechanism' of the Volhard reaction[18]; and it may be added that racemisation has been found to occur when *lævo*-valeric acid is brominated by Volhard's method[19]—a result which must follow if enolisation take place, although susceptible of another explanation.

So far as I can form a judgment, no case has been made out for the view that substitution of halogen for hydrogen under Volhard's conditions differs in its 'mechanism' from substitution in the paraffins. This opinion finds support in the discovery just announced by Leuchs[20] that, while the chief product of the bromination of *dextro*-β-carboxybenzyl-α-hydrindone

is the racemic compound, no less than 10 p.c. is the *dextro*-bromo- derivative; therefore, the inference is clear that in the formation of the latter compound, if not of both, substitution was effected by a process in which migration of the hydrogen atom did not occur.

Attention may now be directed to the question of 'direct substitution,' which, in its simplest form, is encountered in the paraffin series. As will be gathered from the following selection from among the various theories propounded to account for the mechanism of substitution, alternative explanations of the intermediate reactions leading up to substitution in these cases involve either elimination of the hydrogen atom before introduction of the halogen, or addition of the halogen in virtue of the supposed residual valency of both molecules, followed by disruption of the complex thus formed into the known products of the change.

[15] A. Lapworth, *Trans. Chem. Soc.*, 1904, **85**, 31; H. M. Dawson with May S. Leslie, *ibid.*, 1909, **95**, 1860; with R. Wheatley, *ibid.*, 1910, **97**, 2048; with F. Powis, *ibid*, 1912, **101**, 1503.

[16] K. H. Meyer, *Ber.*, 1912, **45**, 2867.

[17] O. Aschan, *Ber.*, 1912, **45**, 1913; 1913, **46**, 2162; K H. Meyer, *Ber.*, 1912, **45**, 2868.

[18] J. Volhard, *loc. cit.*

[19] O. Schütz and W. Marckwald, *Ber.*, 1896, **29**, 58.

[20] H. Leuchs, *Ber.*, 1913, **46**, 2435.

Dealing with these alternatives in the order given, Arrhenius adopts a view of the process of substitution which, including as it does his explanation of optical inversion and racemisation, should perhaps be given in his own words :—

'Every valency linking can be broken; this is true in all cases, since it is a necessary condition for every chemical reaction. An atom or an atomic complex is thereby removed from the molecule, and its place taken by another atom or atomic complex. One must therefore assume, as was first pointed out by Williamson, that the atoms or complexes separate themselves from the molecule from time to time, even when they do not react with other molecules. Consider now a molecule in which four different atoms, A, B, C, and D, are bound to one carbon atom. The atoms A and B, which may possess equal charges, *e.g.*, positive, are therefore separated at times from the molecule, and it may happen that they are both separated at one and the same time. It is therefore possible for them to change places on combining with the carbon atom again. This is synonymous with a transformation of the original molecule into its optical isomer.' [21]

Nef, making use of 'the conception of dissociation in its broadest sense,' is of opinion that the decomposition of ethane into hydrogen and ethylene at 800° 'proves that an extremely small per cent. of [its] molecules must exist at ordinary temperature in an active or dissociated condition,

$$CH_3 \cdot CH_3 \rightarrow CH_3 \cdot CH_2 + H -\text{'}^{22}$$

consequently, when 'chlorine reacts with ethane to give the monochloro- substitution product, we have this reagent in the *active molecular* condition simply uniting by addition with the dissociated ethane particles,

$$\begin{array}{c}Cl = Cl\\ | \quad\quad |\end{array} + H - C_2H_5 \rightarrow \begin{array}{cc}Cl = & Cl\\ | & |\\ H & C_2H_5\end{array} \quad [\rightarrow HCl + C_2H_5Cl.]\text{'}$$

Finally, he draws the conclusion that 'excluding reactions called ionic, a chemical reaction between two substances always first takes place by their union to form an additive compound.'

Michael,[23] in many published papers, has emphasised the view that in the substitution of halogen for hydrogen in a saturated hydrocarbon or saturated acid the principal factors to be taken into account are the mutual chemical attraction of the two elements, on the one hand and that of the halogen and carbon, on the other. By applying his 'positive-negative' hypothesis to the directing influence of 'relatively-positive' methyl, and 'relatively-negative' carboxyl, he draws conclusions about the degree of firmness or looseness with which particular hydrogen atoms are bound to carbon in the molecule, and is thereby able to forecast with some success the position or positions in which replacement of hydrogen by halogen will occur. Flurscheim, in the discussion of the relation between the strength of acids and bases, and the quantitative distribution of affinity in the molecule, also makes use of the idea that the relative degree of firmness or looseness with which a hydrogen atom is held depends on the nature of the other atoms or radicals associated with the same carbon atom.[24] The hydrogen atoms therefore are not to be regarded as retained in the molecule with the same degree of firmness; in other words, valency is not a constant to be measured in units.

It will be gathered therefore that Arrhenius and Nef, from different standpoints, support the idea that separation of hydrogen from the hydrocarbon precedes entry of the substituent into the molecule; Michael and Flürscheim are concerned chiefly with the distribution of valency in the molecule, which determines whether a particular hydrogen atom shall be displaced by hydrogen or

[21] S. Arrhenius, *Theories of Chemistry*, edited by T. Slater Price (Longmans, 1907), p. 76.

[22] J. U. Nef, 'The Fundamental Conceptions underlying the Chemistry of the Carbon Atom,' *J. Amer. Chem. Soc.*, 1904, **26**, 1566.

[23] A. Michael, *Ber.*, 1901, **34**, 4028, covering reference to earlier papers.

[24] B. Flürscheim, *Trans. Chem. Soc.*, 1909, **95**, 721.

not; Kekulé's hypothesis requires addition to precede substitution. Is there any experimental evidence to indicate where the balance of probability lies? I think it can be argued that the phenomena of substitution observed with optically active substances do not lend support to the views of Arrhenius or of Nef, which imply actual or virtual dissociation, but that they point to the intermediate formation of an additive product, which undergoes scission as Kekulé supposed. Such an additive product can be formed only if residual valencies be present in both carbon compound and addendum.

The argument runs thus: Unless valency has fixed direction in space, a conception now abandoned if modern theories of valency be accepted, the conclusion seems to be inevitable that dissociation of the optically active compound:—

$$C\mathrm{WXYZ} \text{ into } \dot{C}\mathrm{WXY} + \mathrm{Z},$$

must lead to racemisation, the radicals W, X, Y, distributing themselves in two-dimensional space, thus destroying the asymmetry; whence it follows that introduction of the substituent, V, into the molecule in place of Z can give rise only to an optically inactive product. Now, it is a well established fact that a radical attached directly to the asymmetric carbon atom may be replaced by another without racemisation following.[25] Therefore, preliminary dissociation being excluded, Kekulé's additive hypothesis remains. But the prolonged study of that remarkable reaction known as the 'Walden inversion' by Emil Fischer, McKenzie, and other investigators has led to results which, if the views formed independently by Fischer,[26] Werner,[27] and Pfeiffer[28] may be accepted, are inexplicable unless a preliminary addition, effected as it is supposed by means of residual valencies, precedes this replacement of the eliminated radical by the substituent.

The Walden inversion may be illustrated by a brief statement of some of the facts discovered in connection with the conversion of optically active chlorosuccinic acid into malic acid

$$\mathrm{R}\cdot C\mathrm{H(OH)}\cdot \mathrm{CO_2H} \rightarrow \mathrm{R}\cdot C\mathrm{HCl}\cdot \mathrm{CO_2H} \rightarrow \mathrm{R}\cdot C\mathrm{H(OH)}\cdot \mathrm{CO_2H}.$$

Walden found that *lævo*-chlorosuccinic acid, obtained from *dextro*-malic acid, furnished either *dextro-* or *lævo*-malic acid, according to the reagent used to effect of the replacement of the Cl by the OH radical.

$$l\text{-chlorosuccinic acid} \begin{array}{l} \nearrow (+\mathrm{Ag_2O}) \rightarrow l\text{-malic acid} \\ \searrow (+\mathrm{KOH}) \rightarrow d\text{-malic acid.} \end{array}$$

And as the corresponding inversion was found to occur with *dextro*-chlorosuccinic acid under similar conditions, a complete cycle of changes can be brought about.[29] That preservation of optical activity, and not racemisation, should accompany the replacement of a radical, attached to the asymmetric carbon atom, by another is a fact of much theoretical interest, as has already been indicated; that a change in the sign of rotation should occur when an exchange of the same radicals is achieved by one reagent and not by another is a mystery, that deepens rather than diminishes with each addition to the list of inversions, already long, in which it has been observed.[30] In all probability the discovery of the Walden

[25] P. Walden, *Ber.*, 1895, **28**, 1297; W. A. Tilden and B. M. C. Marshall, *Trans. Chem. Soc.*, 1895, **67**, 494.

[26] E. Fischer, *Annalen*, 1911, **381**, 123.

[27] A. Werner, *Ber.*, 1911, **44**, 873.

[28] P. Pfeiffer, *Annalen*, 1911, **383**, 123.

[29] P. Walden, *Ber.*, 1896, **29**, 133; 1897, **30**, 3146; 1899, **32**, 1833, 1855.

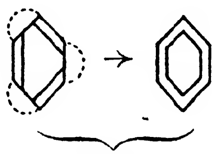
[30] Without the aid of a model it is not possible to show that the production of the *dextro-* or *lævo-* acid may be accounted for by the hypothesis that an intermediate additive compound is formed, which undergoes scission in one or other of two ways. Diagrams of models will be found in Fischer's paper (*loc. cit.* cf. ***Annual Reports on the Progress of Chemistry*** (Gurney and Jackson),

inversion, as Professor Frankland has said, 'may mark an epoch in our views with regard to the mechanism of the process of substitution in general.'[31]

The Structure of the Benzene Molecule.

The abandonment of the theory of the fixed valency unit in favour of the view that the carbon atom has both principal and residual valencies has raised afresh that perennial topic of controversy—the structure of the benzene molecule. Probably few will contest the statement that for practical purposes only three formulæ have emerged from the long discussion of the problem, viz. Kekulé's oscillation formula with fixed valency units, for which much physical evidence has been pleaded: Thiele's formula, in which his theory of 'conjugated double linkings' is applied to the Kekulé formula, with the consequence that the three double linkings disappear owing to self-neutralisation of the partial valencies, the benzene molecule thus containing six inactive double linkings;[32] and Armstrong's 'centric' formula, in which by its residual valency 'each individual carbon atom exercises an influence upon each and every other carbon atom.'[33] The dotted lines indicate the residual valencies.

Kekulé.



Thiele.

Armstrong.

The discovery of *cyclo*octatetraene has brought a new interest into the discussion,[34] for the structural formula assigned to this hydrocarbon shows alternate single and double linkings as in Kekulé's symbol, and the optical behaviour (refractivity) corresponds with that of benzene.

$$\begin{array}{ccc} & CH = CH & \\ / & & \backslash \\ CH & & CH \\ \| & & \| \\ CH & & CH \\ \backslash & & / \\ & CH = CH & \end{array}$$

But its chemical properties are entirely different from those of benzene; it forms compounds not by substitution but by addition, and it has the reactivities of a highly unsaturated compound. If these experimental results be accepted, then—as Willstatter shows—the peculiar properties of benzene are not to be explained by Kekulé's or Thiele's formula, and the verdict is given in favour of the 'centric' symbol—that earliest embodiment of the conception of residual valency, which Armstrong later turned to such good account in the quinonoid theory of colour identified with his name.

The reference to the optical behaviour of *cyclo*octatetraene may perhaps suggest the inquiry: Do not the physical properties of the carbon compounds throw light on the questions that have been raised? A little consideration will show that, on the contrary, the answer must be: It is only by chemical evidence that physical data can be interpreted or corroborated, and in the absence of such evidence the 'additive' results which accrue from physical observations have no bearing on questions involving the determination of structure or the structural transformations which accompany a chemical change. For example,

1911, **8**, 67), and to illustrate Werner's hypothesis, which is more explicit than Fischer's, in a paper by W. E. Garner (*Proc. Chem. Soc.*, 1913, **29**, 200).

[31] P. F. Frankland, 'The Walden Inversion,' Presidential Address to the Chemical Society (*Trans. Chem. Soc.*, 1913, **103**, 713).

[32] J. Theile, *Annalen*, 1899, **306**, 126.

[33] H. E. Armstrong, *Trans. Chem. Soc.*, 1897, **51**, 264 (footnote).

[34] R. Willstätter and E. Waser, *Ber.*, 1911, **44**, 3423.

the anomalous results obtained by Brühl and by Sir William Perkin[35] in the investigation of the refractivity and the magnetic rotation of certain unsaturated compounds, remained without explanation until Thiele in 1899, by his hypothesis of partial valency, accounted for the comparative inactivity of the central pair of carbon atoms in compounds of this type—compounds which are characterised by containing alternate single and double linkings in their formulæ

$$\cdot \dot{C}H : CH \cdot \dot{C}H : CH \cdot \rightarrow \cdot CHBr \cdot CH : CH \cdot CHBr \cdot$$

This conception of Thiele's has both focussed attention on the distribution of valency within the molecule, contributing largely to the wide acceptance of theories of valency such as Werner's, and given to the study of physical properties—especially those 'constitutive' properties of refraction, dispersion, and magnetic rotation—an impetus which has by no means spent its force. Further, the occurrence of this anomaly, 'exaltation' as it is called, is now relied on as evidence of the presence of this particular distribution of valency, with results which in Auwers' hands have furnished important clues to the structural formulæ of terpenes and other compounds.

As additive properties become constitutive, so the value of a knowledge of the physical properties of a substance will tend to increase, but there is little ground for hope that the problem of the constitution of benzene will be solved from the physical side. The controversy which has arisen between Hantzsch and Auwers regarding the physical properties of *cyclo*octatetraene in relation to its chemical structure is a case in point;[36] the absence of optical exaltation in this hydrocarbon is wholly unexpected, but, on the other hand, the type of compound is entirely new. With benzene also the distribution of valency within the molecule differs from that in any known compound; our knowledge of it, admittedly far from complete, has been gained from the chemical side, and is summarised in the various structural formulæ; but the limitations of the physical method of attack can be traced from Thomsen's endeavour to determine its structure from thermochemical data[37] to the more recent invention of isorropesis. And, despite the evidence obtained from refractivities, we may not unreasonably demur to the suggestion that derivatives of benzene, which by their behaviour towards substituting agents show themselves to be wide apart in chemical properties, such as nitrobenzene and aniline on the one hand or chlorobenzene and phenol on the other, should respectively be classified together.[38] Undoubtedly, most useful information is obtained from a comparison of the physical properties of two related substances, the exact constitution of one of which is uncertain, but that of the other known. Therefore, bearing in mind the great development that has taken place recently in the correlation of physical properties with chemical constitution by methods based on refraction and absorption, every chemist will welcome the entry of Dr. Lowry into that field of research on the relation between magnetic rotation and structure, which for all time will be associated with Sir William Perkin's name.

Substitution in the Benzene Series.

Turning now to a discussion of the problem of substitution in cyclic compounds, one important factor must not be overlooked; the even distribution of the residual affinity of the benzene molecule is disturbed by the introduction of a substituent. The study of substitution in benzene derivatives indicates that, as a consequence of this disturbance, a directing influence comes into play which, when the substituent is changed, may vary in the effect it exercises on the course of substitution.

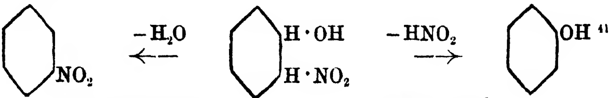
[35] *Cf.* J. W. Bruhl, *Ber.*, 1907, **40**, 878; Sir W. H. Perkin, *Trans. Chem. Soc.*, 1907, **91**, 806, for references to earlier papers.

[36] A. Hantzsch, *Ber.*, 1912, **45**, 563; K. Auwers, *ibid.*, 971.

[37] *Cf.* H. E. Armstrong, *Phil. Mag.*, 1887 [v.] **23**, 73; J. W. Brühl, *J. prakt. Chem.*, 1887 [ii.] **35**, 181, 209.

[38] *Cf.* J. W. Brühl, *Zeit. physikal. Chem.*, 1894, **16**, 220; Smiles, *Relations between Chemical Constitution and Physical Properties* (Longmans, 1910), p. 299.

Arising probably from this even distribution of valency, it is characteristic of benzene to furnish additive compounds in which six atoms of hydrogen or a halogen, but not two or four, become attached symmetrically to the molecule; substitution, however, occurs when a catalyser is present, such as the aluminium-mercury couple for halogenation, or sulphuric acid for nitration or sulphonation, leading initially to the production of mono- substituted derivatives. Whether the catalyser by association with the benzene molecule[39] limits this additive capacity, or whether its function is to promote the elimination of the halogen acid or water respectively,[40] is still a subject of discussion, but in the absence of a reaction of additive type it is not easy to account for facts such as the production of a certain amount of trinitrophenol when benzene is nitrated in the absence of sulphuric acid.



(in presence of sulphuric acid (in absence of sulphuric acid)

The much-debated questions still remain: Why and by what mechanism, when a second or third substituent is introduced into the molecule, is the orientation of the isomeric products determined by the radical or radicals already present? For disubstitution, the *ortho-para-* and the *meta*-laws have been deduced, and the radicals which respectively promote mainly *ortho-para-* substitution on the one hand, and *meta-* substitution on the other have been catalogued.[42] But these laws take account only of the orientation of the chief product or products, whereas all three derivatives, *ortho*, *meta*, and *para*, have been detected in most of the reactions studied, and their relative proportion in many cases is known to depend on the conditions, being affected by such influences as variation in temperature or in the medium employed. Nitration of acetanilide, for example, furnishes a mixture of *ortho-* and *para*-nitroacetanilide, but of aniline in the presence of much sulphuric acid yields chiefly *meta*-nitroaniline.[43] And, to illustrate the inadequacy of the *meta*-law, the fact that sulphonation of benzenesulphonic acid with concentrated sulphuric acid at 230°-240° furnishes an equilibrium mixture of the *meta-* and *para*-disulphonic acids in the proportion of 2 :1 may be quoted.[44]

In the exploration of this field many workers have participated, but the results, recorded almost as often in patent specifications as in journals, are seldom quantitative, so great is the difficulty at times in isolating the minor product or products of the change. Recently, however, by a most ingenious use of melting-point curves and density determinations, Holleman and his collaborators have carried out an exhaustive series of substitutions with small quantities of material and under known conditions;[45] yet after a survey of the whole field the conclusions reached are :—

1. That uncertainty cannot be removed until some basis exists for different reactions to be carried out under comparable conditions.[46]

2. That even if the relative amounts of the isomerides formed when a

[39] B. N. Menschutkin, *Abstr. Chem. Soc.*, 1912, **102**, i. 98-100.

[40] *Cf.* H. E. Armstrong, *Trans. Chem. Soc.*, 1887, **51**, 263.

[41] The phenol by nitration forming the trinitro- derivative (picric acid), Armstrong and Rossiter, also Groves, *Proc. Chem. Soc.*, 1891, **7**, 89.

[42] *Cf.* Noelting, *Ber.*, 1876, **9**, 1797; Armstrong, *Trans. Chem. Soc.*, 1887, **51**, 258; Crum Brown and Gibson, *ibid.*, 1892, **61**, 367.

[43] Hübner, *Annalen*, 1881, **208**, 299.

[44] J. J. Polak, *Rec. trav. chim.*, 1910, [ii.] **14**, 416; R. Behrend and M. Mertelsmann, *Annalen*, 1911, **378**, 352.

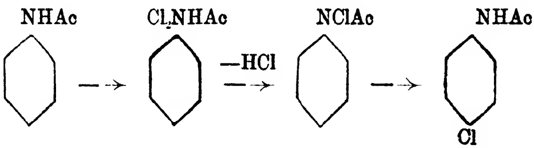
[45] A. F. Holleman, *Die direkte Einführung von Substituenten in den Benzolkern* (Veit & Co., Leipzig, 1910), p. 215.

[46] For example, nitration is effected chiefly at low temperatures, but sulphonation of mono- substituted benzenes at temperatures higher than the ordinary, which if employed in nitration would lead to mixed products.

radical C is introduced into each of the mono- substitution derivatives $C_6H_5 \cdot A$ and $C_6H_5 \cdot B$ be known, it is not possible to calculate the proportion in which the isomerides $C_6H_3 \cdot ABC$ will be produced when the radical C is substituted in the compound $C_6H_4 \cdot AB$.

Although the validity of the *ortho-para-* and of the *meta-* laws may be impeached, they serve as a first approximation, and many theories have been propounded to account for them. Armstrong has suggested that in *ortho-para-*substitution the additive compound is formed by association of the addendum with the carbon atom carrying the radical already substituted in the molecule,[47] whereas in *meta-* substitution it arises by union of the addendum with this radical,[48] transformation to the respective disubstitution derivatives being effected possibly in step-by-step progression, as conjectured by Lapworth.[49] Holleman, who also adopts the additive hypothesis, is of the opinion that the radical already present in the molecule may promote or retard the association of the addendum with the pair of carbon atoms, to one of which it is itself attached. By the operation of the first of the alternatives an *ortho-* and by conjugation a *para-* derivative will arise; from the second a *meta-* derivative will result, when scission of the additive compound ensues. Holleman's is the only hypothesis which has been submitted to the test of quantitative investigation, and although, as already mentioned, the results do not suggest that finality has been reached, it marks an advance in the study of this obscure problem.[50]

No discussion of substitution in the benzene series would be adequate without reference to the remarkable behaviour of amines and phenols. Unlike other mono- substitution derivatives, which do not differ markedly from benzene in reactivity, these furnish mono-, di-, and tri-derivatives very readily. With aniline or acetanilide, substitution occurs first of all in the side chain, being followed under appropriate conditions by removal of the substituent from the amino- group and entry into positions relatively *ortho-*, *para-*, or both *ortho-* and *para-* to it. The earliest of these changes to be studied was the transformation of methylaniline into *para*-toluidine; many of them have been discovered by Chattaway and his collaborators, and until a critical study of the chlorination of acetanilide was undertaken by Orton and Jones,[51] it was held that they were of the type:



From the dynamics of the reaction, which occurs only in the presence of hydrochloric acid, it is now known that in the production of acet*para*chloroaniline intra-molecular transformation from the side chain to the ring does not take

[47] Kinetic studies of the chlorination and bromination of toluene, $C_6H_5 \cdot CH_3$, however, gave no indication of the production of an intermediate additive compound of the hydrocarbon and addendum (cf. Holleman, Polak, van der Laan, and Euwes, *Rec. trav. chim.*, 1908, **27**, 435; Bruner and Dluska, *Bull. Acad. Sci.*, Cracow, 1907, 693; Bancroft, *J. Physical Chem.*, 1908, **12**, 417; Cohen, Dawson, Blockey, and Woodmansey, *Trans. Chem. Soc.*, 1910, **97**, 1623.

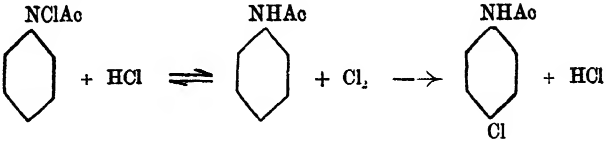
[48] H. E. Armstrong, *Trans. Chem. Soc.*, 1887, **51**, 258.

[49] A. Lapworth, *Trans. Chem. Soc.*, 1898, **73**, 454; 1901, **79**, 1265.

[50] It should be mentioned that other views, based on the loosening or strengthening of the affinity of the hydrogen atoms situated in *ortho-*, *para-* or in *meta-* positions, brought about by the disturbing influence of the radical already present in the molecule on the valency of the carbon atom to which it is attached, and therefore on that of the other five carbon atoms, have been advanced by Flürscheim (*J. prakt. Chem.*, 1902 [ii.], **66**, 321), Tschitschibabin (*ibid.*, 1912 [ii.], **86**, 397), and others.

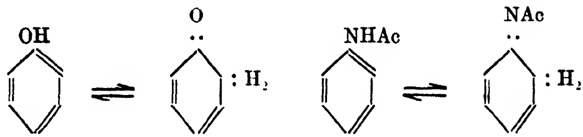
[51] K. J. P. Orton and W. J. Jones, British Association Report, 1910, p. 96; *Trans. Chem. Soc.*, 1909, **95**, 1456.

place, the agent promoting the substitution being chlorine arising from the following series of reactions :—



As bromination has been shown to follow the same course, it is evident that no secure foundation now exists for the view, formerly widely held, that the reactivity of amines is intimately connected with the variable valency of nitrogen leading to initial substitution in the side chain.

Even were this view, now discredited, still applicable to the amines, it could not be extended with the same certainty to the phenols. Hence, in explanation of the rigid adherence to the *ortho-para-* law observed among the mono- substitution derivatives of these two groups of compounds, it is noteworthy that Thiele,[52] for the phenols, suggests that the reactivity may be due to these substances being stable enolic forms of ketodihydrobenzenes, and that Orton,[53] for the amines, conjectures that it may arise from the formation of dynamic isomerides of quinonoid structure :



How far these suggestions may open up a new field of inquiry into the 'mechanism' of substitution remains to be seen; it is at least interesting that their extension to the naphthalene series shows that not only does the reactivity of the naphthols and of a-naphthylamine recall that of phenol and aniline, but the orientation of their mono- substitution derivatives [54] in almost every case is the same as that of one or other of the six naphthaquinones, the existence of which has been predicted by Willstatter.[55]

Symmetric and Asymmetric Syntheses.

It must not be supposed that the 'mechanism' of substitution can be explained by reference only to the examples of this type of reaction which have been mentioned, or that the summary attempted in the restricted field of the replacement of hydrogen by halogen is a complete picture of all the different views advanced to account for this chemical change. Rather, the effort has been made to indicate in broad outline the difficulties that beset any exploration of that debateable region which lies between the two sides of a chemical equation. But, as the wonderful story of carbon chemistry shows, the failure to comprehend the processes operative in substitution does not impede rapid progress in other directions. The study of the mobility of radicals, desmotropy being only one of many examples of this phenomenon, continues to present fresh problems, of which that raised by Thorpe[56] in connection with the mobile hydrogen atom of glutaconic and aconitic acids may be mentioned, as it revives a question of old standing : Do free units of valency exist in carbon compounds? The syntheses of caffeine and certain alkaloids, of sugars and peptone-like poly-

[52] J. Thiele, *Annalen*, 1899, **306**, 129.
[53] British Association Report, 1910, p. 96.
[54] *Cf.* W. P. Wynne, art. 'Naphthalene,' Thorpe's *Dictionary of Applied Chemistry*, second edition, vol. 3 (Longmans, 1912).
[55] R. Willstätter and J. Parnas, *Ber.*, 1907, **40**, 1406.
[56] N. Bland and J. F. Thorpe, *Trans. Chem. Soc.*, 1912, **101**, 871, 1490.

peptides, of natural terpenes and camphor, of indigo and rubber, are well-known achievements, while natural processes, in which enzyme action plays a part, are yielding their closely guarded secrets to the persistent inquiry of Armstrong and his collaborators, who are probing the relationship between enzyme and substrate which Emil Fischer pictured as that of lock and key. Further, there is that large field of work which includes not only the Walden inversion but new problems of asymmetry, with which the names of Frankland, Pope, Werner, and others are associated; while Barlow and Pope's conception of the relation of valency to atomic volume, by correlating crystalline structure with the composition, constitution, and configuration of carbon compounds, has given a new interest to the study of crystallography.

Nor is progress less rapid in that other important branch of chemistry—the unravelling of the structure of natural products. The constitution of rubber is approximately known; most of the alkaloids have been explored with a greater or less degree of completeness; and now the study of starch,[57] chlorophyll, and hæmatin (the non-proteid constituent of hæmoglobin) [58] has been taken up afresh during the last three years, with results which, in the case of the two latter, eclipse in importance and interest all that was previously known. In whatever direction we may look, there is the same evidence that we can take to pieces the most complicated structure which nature has devised, and by the aid of valency conceptions can fit the pieces into a formula which is an epitome of the chemical activities of the molecule. Again, in many cases the resources of our laboratories enable us to build up the structure thus displayed, and to establish the identity of nature's product and our own. Nevertheless, the fact remains that all these syntheses leave untouched and unexplained the profound difference between the conditions we find necessary to achieve our purpose and those by which the plant or animal carries on its work in presence of water and at a temperature differing only slightly from the normal. It is, of course, a well-known fact that an enzyme under the appropriate conditions can bring about the same chemical transformation of a substrate as is effected by the living cell from which it can be separated; but our knowledge of these complex, ill-defined, nitrogenous organic compounds is relatively very meagre; they are difficult to purify, and their composition—apart from any question of structure—is largely unknown. Yet because Wöhler chanced to discover that urea can be produced synthetically from an inorganic source the conclusion is not infrequently drawn that all chemical changes in living substance are brought about by ordinary chemical forces.[59] Probably everyone present will concur in that view, but the assent, if given, can hardly arise from a consideration of the facts, of which there is no great store. Where so little is known accurately, chemistry is not on very safe ground if she infer the rest. What common basis of comparison exists between Wöhler's process and the metabolic changes by which urea is produced in the living body? What evidence have we that because an enzyme and an inorganic agent under different conditions give rise to the same end product, the driving force is the same, although the lines along which it is exercised are very different? I think it is not the least of the many services which Professor Meldola has rendered to chemistry, that he has given us this warning: 'If we have gone so far beyond Nature as to make it appear unimportant whether an

[57] H. Pringsheim and H. Langshans, *Ber.* 1912, **45**, 2533.

[58] For summaries of Willstätter's and Marchlewski's researches on chlorophyll, and of Piloty's on hæmatin, *cf. Annual Reports on the Progress of Chemistry* (Gurney and Jackson) 1911, **8**, 144–52; 1912, **9**, 165–72.

[59] 'Quite similar changes can be produced outside the body (*in vitro*) by the employment of methods of a purely physical and chemical nature. It is true that we are not yet familiar with all the intermediate stages of transformation of the materials which are taken in by the living body into the materials which are given out from it. But since the initial processes and the final results are the same as they would be on the assumption that the changes are brought about in conformity with the known laws of chemistry and physics, we may fairly conclude that all changes in living substance are brought about by ordinary chemical and physical forces."- Sir Edward Schäfer, President's Address at the Dundee Meeting, British Association Report, 1912, p. 9.

organic compound is producible by vital chemistry or not, we are running the risk of blockading whole regions of undiscovered modes of chemical action by falling into the belief that known laboratory methods are the equivalents of unknown vital methods.'[60]

I turn now to a no less interesting question than that involved in enzyme reactions, namely, the wide distribution in plants and animals of single asymmetric substances which if synthesised in the laboratory would be produced as inactive mixtures of both asymmetric forms. It has been argued that the occurrence of racemic compounds in nature, although infrequent, is a proof that in the organism, as *in vitro*, they are in all cases the initial products from which, when separated into antipodes, one of the asymmetric compounds is utilised in the life processes and the other left. But whether this be the case, or whether only the one asymmetric form result from the synthesis, Pasteur firmly held the view that the production of single asymmetric compounds or their isolation from the inactive mixture of the two forms is the prerogative of life. Three methods were devised by Pasteur to effect this isolation, and in only one of them are living organisms—yeasts or moulds—employed; but Professor Japp, in his address to this Section at Bristol in 1898, emphasised the fact, hitherto overlooked, that in the two others, nevertheless, 'a guiding power [is exercised by the operator] which is akin in its results to that of the living organism, and is entirely beyond the reach of the symmetric forces of inorganic nature.' Hence, to quote again from his address, 'only the living organism with its asymmetric tissues, or the asymmetric products of the living organism, or the living intelligence with its conception of asymmetry, can [bring about the isolation of the single asymmetric compound]. Only asymmetry can beget asymmetry.' After an exhaustive review of the subject, Japp came to the conclusion that the failure to synthesise single asymmetric compounds without the intervention, either direct or indirect, of life is due to a permanent disability, and although—as was to be expected—this conclusion was challenged,[61] the only 'asymmetric syntheses' effected since that time have been operations controlled by the chemical association of an optically active substance with the compound undergoing the synthetical change.[62]

Recently the problem has assumed a more hopeful character. Ostromisslensky[63] in 1908 made the remarkable discovery that inactive asparagine, which is not racemic but a mixture of the *dextro-* and *lævo*-forms in molecular proportion, gave a separation of one or other isomeride when its saturated solution was inoculated by a crystal of glycine—a substance devoid of asymmetry. Now Erlenmeyer claims to have achieved a true asymmetric synthesis by boiling an aqueous solution of inactive asparagine for sixteen hours, when by crystallisation part of the *dextro*-form separated in an almost pure state.[64]. The theoretical conclusions which led to this investigation are of much interest because they raise afresh the question whether without displacement of the individual radicals, and apart from antipodes, more than one compound can exist, in the molecule of which two carbon atoms are united by a single linking.[65] As an illustration, reference may be made to the malic-acid series, in which three optically active compounds are known, the *dextro*-acid, the *lævo*-acid, and Aberson's acid.[66] In the *lævo*-series the three isomerides obtainable by rotation

[60] R. Meldola, *The Chemical Synthesis of Vital Products* (Arnold, 1904), p. vii.

[61] F. R. Japp, *Stereochemistry and Vitalism.* Presidential Address to Section B (Bristol), British Association Report, 1898, p. 826; *cf.* K. Pearson, *Nature*, 1898, **58**, 495; G. Errara; F. R. Japp, *ibid.* 616; Ulpiani and Condelli, *Gazz. chim. ital.* 1900, **30** [i], 344; Byk, *Ber.* 1904, **37**, 4696; Henle and Haakh, *Ber.* 1908, **41**, 4261; Byk, *Ber.* 1909, **42**, 141.

[62] *Cf. inter alia*, McKenzie, *Trans. Chem. Soc.*, 1905, **87**, 1373.

[63] I. von Ostromisslensky, *Ber.*, 1908, **41**, 3035.

[64] E. Erlenmeyer, *Biochem. Zeitsch.* 1913, **52**, 439.

[65] *Cf.* J. Wislicenus, *Ueber die räumliche Anordnung der Atome in organischen Molekulen* (Hirkel, Leipzig, 1889), 28; K. Auwers and V. Meyer, *Ber.*, 1888, 21, 791.

[66] J. H. Aberson, *Ber.*, 1898, **31**, 1432; P. Walden, *Ber.*, 1899, **32**, 2720.

of one of the carbon atoms with its attached radicals relatively to the other would be

H	H	H
$OH \cdot C \cdot CO_2H$	$OH \cdot C \cdot CO_2H$	$OH \cdot C \cdot CO_2H$
$CO_2H \cdot C \cdot H$	$H \cdot C \cdot CO_2H$	$H \cdot C \cdot H$
H	H	CO_2H
lævo-acid, $[\alpha]_D - 5{\cdot}8°$	(not isolated)	Aberson's acid, $[\alpha]_D + 9{\cdot}8°$

With the inactive asparagine it is supposed by Erlenmeyer that prolonged heating in aqueous solution produces a rotation of this type, possibly to an unequal extent or in opposite directions in the *dextro-* and *lævo*-forms, whereby the products being no longer antipodes become separable by ordinary laboratory methods. It is too early yet to say whether, by exclusion of all asymmetric influences, the riddle has been solved, but it is easy to understand with what interest confirmation of Erlenmeyer's results is awaited.

Honours Students and Post-Graduate Scholarships.

In bringing this address to a conclusion, it will not be an innovation if I refer—it shall be only briefly—to the training of those who will carry on and amplify the work which we in this generation have attempted to do. This section stands for the advancement of chemistry, which includes, so closely are pure and applied chemistry intertwined, the advancement of chemistry as applied to industry. Once again the cry has been raised in the press[67] that chemists trained in our Universities are of little value in industrial pursuits; they are too academic; they are not worth their wage—little as that often is, whether judged by a labourer's hire or the cost of a university training. It may be so. On the other hand, it is possible the employer obtains all that he pays for, and by paying more would receive in return much more by the inducement offered to more highly trained men to enter the field. Three years' training for the ordinary degree cannot carry a student very far in chemistry, and this preliminary training—for it is little more—is insufficient to equip the young graduate for more than routine work. With the Honours student it is otherwise. He must either enter on his three years' residence at a University with a knowledge which does not fall below the requirements of the Intermediate Examination, and devote the greater part of his time to his Honours subject, or he must be prepared to spend a fourth year to reach the necessary standard. More highly equipped in the academic sense than a man who has worked only for the ordinary degree, he undoubtedly is, yet there is seldom time to begin his training in research methods or in methods of commercial analysis where rapidity rather than extreme accuracy is the object in view.

Two reforms, I venture to think, are needed : the first would avoid early specialisation, which is apt to be disastrous, the second would encourage post-graduate training in directions where the student's inclinations or aptitude may be stimulated and developed. If the Civic Universities, established in virtue of charters drafted mainly on similar lines and inspired by similar aims, could come to some agreement requiring three years' residence, subsequent to the Intermediate, for an Honours degree in chemistry, the first reform would be effected—it is a measure for which a strong case can be made out. If, further, they could see their way to standardise their Ordinances and Regulations for the M.Sc. degree, cease to confer it on Honours graduates of one or more years' seniority in return for payment of a fee, and confine it to graduates—not necessarily Honours graduates—who have carried out an approved piece of research during not less than one academic year, Selection Committees, Boards of Directors, or individual employers would have some clue to the type of man before them. I would go further and suggest that the interchange of Honours graduates between the Civic Universities, or between them and other Universities or Colleges, if it could be arranged, would be of much benefit to the student himself. No University in this country is wealthy enough to attract to its service teachers who are pre-eminent in each branch of chemistry. How great, then,

[67] Cf. *The Times*, Engineering Suppl., 1913, May 7, 21, 28, June 4, 11, 18.

would be the gain to an Honours graduate working for the M.Sc. degree, if, instead of being associated with the same teacher during the whole of his academic career, he could migrate from the place which had trained him to spend part, or the whole, of his time in the laboratory of an Armstrong, a Donnan, a Perkin, or a Ramsay, during that most critical period when he is sorting out his own ideas and learning how to use his fingers and his wits. But whether enforcement of the longer training for the Honours degree be possible; whether a research degree as a step to the Doctorate be desirable or practicable, there can be no doubt that the urgent need of the present time is the provision of scholarships and exhibitions, sufficient in value to secure at least a bare livelihood, for post-graduate work. He who is able to convert Education Committees and private donors to the view that a far better return for the money could be assured if part of the large expenditure on scholarships for matriculated or non-matriculated students were diverted to post-graduate purposes, will have done a service to science and the State the value of which, in my opinion, cannot be overestimated.

The following Papers and Reports were then read :—

1. *The Progressive Bromination of Toluene.* *By* Julius B. Cohen, *F.R.S.*, *and* P. K. Dutt.

A. K. Miller[1] studied the action of bromine on ortho- and para-bromotoluene separately and identified the dibromotoluenes formed in each case by oxidising the products to the corresponding benzoic acids and fractionally crystallising the barium salts. His results may be summarised as follows : Ortho-bromotoluene gave the 2 : 5 dibromo- compound as the principal product together with a smaller quantity of the 2 : 4 derivative; para-bromotoluene gave, as the main product, 3 : 4 derivative and a smaller quantity of the 2 . 4 compound.

In comparing these results with those of chlorination of ortho- and para-chlorotoluenes[2] considerable discrepancies appear. In the case of chlorination of ortho-chlorotoluene the main products were the 2 : 4 and 2 : 3, and a similar quantity of 2 : 6 derivative, whilst the presence of 2 : 5 compound seemed probable but not certain. In the case of the para- compound, the 2 : 4 is the main product and not 3 : 4, as found by Miller in the case of bromination.

Considering this difference in the orienting effect of the two halogens we thought it desirable to repeat Miller's work and extend it along the same lines as were followed in the case of chlorination.

Incidentally, we examined the mixed monobromo-toluenes—the first product of the action of bromine on toluene—to detect any trace of the meta- compound if formed. We also carried our investigation as far as the tribromo- stage.

In the following table the results of bromination and chlorination are given side by side, the principal product being placed first in each case and a trace indicated by brackets :—

—		Bromination Products	Chlorination Products
	Toluene.	Ortho-, para- (meta).	Ortho-, para-.
Monohalogen Compounds	Ortho- compound.	2 : 5 ; 2 : 4.	2 : 4 ; 2 : 3 ; 2 : 6 ; (2 : 5).
	Para- ,,	2 : 4 ; 3 : 4.	2 : 4 ; 3 : 4.
	Meta- ,,	2 : 5 ; 3 : 4 ; (3 : 5).	2 : 5 ; 3 : 4.
Dihalogen Compounds	2 : 3.	2 : 3 : 6 ; 2 : 3 : 5.	2 : 3 : 4.
	2 : 4.	2 : 4 : 5 ; (2 : 4 : 6)	2 : 4 : 5 ; 2 : 3 : 4 ; (2 : 4 : 6).
	2 : 5.	2 : 4 : 5 ; (2 : 3 : 5) ; (2 : 3 : 6).	2 : 3 : 6 ; 2 : 4 : 5.
	2 : 6	2 : 3 : 6.	2 : 3 : 6.
	3 : 4.	2 : 4 : 5 ; (3 : 4 : 5).	2 : 4 : 5.
	3 : 5.	2 : 3 : 5.	2 : 3 : 5.

[1] *Trans. Chem. Soc.* 1892, **61**, 1023

[2] Cohen and Dakin, *Trans. Chem. Soc.* 1901, **79**, 1111.

Attention is directed to the difference produced by chlorination and bromination of orthohaloid toluenes in the orienting effect, which is most marked in the case of the monohalogen compound and the 2 : 3 and 2 : 5 halogen derivatives.

2. *The Saturated Acids of Linseed Oil.* *By* R. S. Morrell, *M.A., Ph.D.*

A summary of the literature on linseed oil in Czapek's 'Biochemie der Pflanzen,' 1, 121, and Lewkowitsch's 'Oils, Fats, and Waxes' (fourth edition), 2, 50, shows that in addition to the unsaturated acids, linolenic, linolic, and oleic, the saturated acids, palmitic and myristic, have been identified in about equal proportions.

Haller ('Compt. rendus,' 146, 259, 1906), by fractional distillation of the methyl esters obtained from linseed oil, was able to separate appreciable quantities of palmitic and stearic acids and much smaller quantities of arachidic acid.

The occurrence of stearic acid in linseed oil seemed worthy of further investigation, not only for its practical importance, but also for its relationship to the unsaturated acids present. It is well known that when linseed oil is heated with lead oxide and allowed to cool a solid separates out, whose quantity is increased by addition of petroleum or turpentine. No record of a systematic investigation of this deposit has been published. The lead salts obtained from linseed oil from different sources were freed from unsaturated acids, and yielded a mixture of acids, melting-point 52-54° C., molecular weight 282-3, and iodine value 5 8. The acids consisted of stearic acid, with palmitic acid, and a trace of oleic acid. No myristic or arachidic acids were found. An investigation of the mixture by the methods recommended for the separation of saturated fatty acids showed that it consisted of 68 per cent. stearic acid, and the remainder of palmitic acid, with 4·5 per cent. oleic acid. The most satisfactory results were given by a combination of the methods devised by Hehner and Mitchell ('Analyst,' 1896, 321) and Kreis and Hafner ('Ber.,' 36, 2,766, 1913). The separation of the acids was very tedious, and a much more satisfactory method is desired. When more than two acids are present the quantitative separation is a matter of great difficulty.

3. *A Series of Mixtures of Nitro-compounds and Amines which are coloured only in the liquid state.* *By* C. K. Tinkler, *D.Sc.*

Whilst engaged in an investigation as to the cause of the colour of certain alkyl iodides of cyclic bases in 1908, it was noticed by the author that in some cases nitro-compounds like these alkyl iodides, when dissolved in fused diphenylamine, gave coloured solutions. In the case of the nitro-compounds, however, the colour often disappears on cooling. The investigation in connection with nitro-compounds was not pursued very far at that time, but it has recently been extended.

The most suitable substances for the demonstration of this phenomenon are mixtures of diphenylamine with one of the following nitro-compounds : *o*, *m*, and *p* chlor-nitrobenzene, *m* and *p*-nitrobenzaldehyde, *p*-bromo-nitrobenzene, tetranitromethane. By enclosing one of these mixtures between two test-tubes placed one inside the other the phenomenon is well demonstrated. Thus, a mixture of diphenylamine and para-chlor-nitrobenzene, which is colourless at the ordinary temperature, acquires a reddish yellow colour when held in the hand, and loses this colour when the temperature falls.

A mixture of diphenylamine and *p*-nitro-benzaldehyde shows a deep red colour at one degree above body temperature, returning to the colourless state on cooling. A mixture of diphenylamine and tetranitromethane shows a dark brown, nearly black, colouration, but on cooling in a mixture of ice and salt this colour entirely disappears. On repeating the last experiment several times, however, a permanent green colouring is produced, which is probably due to the decomposition of the nitro-compound. In other cases the mixture undergoes no change on keeping. Thus, a mixture of diphenylamine and *p*-chlor-nitrobenzene prepared five years ago shows the phenomenon as well now as when first prepared.

Attempts to precipitate the coloured substances from solution give interesting results. Thus, by treating a concentrated alcoholic solution of a mixture of diphenylamine and *p*-nitrobenzaldehyde with water a red, semi-solid mass is obtained, which, however, on complete solidification, produced by agitation, is perfectly white.

From analogy with compounds of amines and nitro-compounds, such as trinitrobenzene, picryl chloride, &c., prepared by previous investigators, it would appear that the colour of these mixtures under consideration is probably due to the combination of nitro-compound and amine in the liquid state only, and hence various physico-chemical investigations of the fused mixtures were undertaken.

The following results were obtained in this connection :—

1. No evidence was obtained of the separation of a compound in the solid state by cooling a fused mixture.

2. No break was observed in the curve, densities : composition, either in the case of a mixture showing the phenomenon, or in the case of a mixture of obenzene and diphenylamine where a compound exists in the solid state.

3. A very slight rise of temperature was observed when the fused constituents re mixed.

4. No direct evidence of the formation of a compound was obtained by the determination of the viscosity : composition curve for one of the mixtures showing the phenomenon.

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4. *The Influence of Chemical Constitution on the Thermal Properties of Binary Mixtures. By* Ernest Vanstone.

Binary mixtures of compounds of the type Ph α β Ph have been investigated by the method of thermal analysis. Thermal diagrams have been obtained for mixtures of benzoin with each of the following substances :—Benzylaniline, benzylidene aniline, dibenzyl, azobenzene, benzil, hydrazobenzene, benzanilide, and also for mixtures of benzil with each of the following: Dibenzyl, azobenzene, stilbene, hydrobenzoin, benzanilide. The diagram for benzylidene aniline—benzanilide—has also been obtained. In all cases the thermal diagram has a V form, containing one eutectic point. In no case was there any evidence of compound formation, but solid solutions are formed to a limited extent in all cases. For benzoin eutectics both the temperature and concentration of the eutectic mixture is a function of the melting-point of the other constituent. This is seen from the table below :—

Benzoin Eutectics.

Substance	M.P.	Eutectic Temp.	Concentration. Per cent. Benzoin
	Deg. C.	Deg. C.	
Benzylaniline	34·2	32·4	3
Benzylidene aniline . . .	49·8	47·0	3
Dibenzyl	51·2	50·2	3·5
Azobenzene	66·2	63·8	6·0
Benzil	94·2	84·0	17·8
Hydrazobenzene	130·5	98·4	42
Benzanilide	160·8	116·6	64

The molecular volumes of the various substances have been determined. It was found that at the temperature of the melting-point the unsaturated substance has often a greater molecular volume than the saturated substance. No relation could be found between molecular volumes and eutectic points. Binary mixtures of benzylidene aniline, benzyl aniline, stilbene and dibenzyl with these substances were also discussed.

5. *The Influence of the Presence of Gas on the Inflammability of Coal Dust in Air.* By Professor W. M. Thornton, *D.Sc.*

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6. *Decomposition Products of Indigo in the Vat.* *By* H. Ehrhardt.

7. *Report on the Study of Hydro-aromatic Substances.* See Reports, p. 135.

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8. *Report on the Transformation of Aromatic Nitroamines.* See Reports, p. 136.

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9. *Report on Dynamic Isomerism.*—See Reports, p. 141.

10. *Report on the Study of Plant Enzymes.*—See Reports, p. 143.

FRIDAY, SEPTEMBER 12.

Metallurgical Division.

The following Papers were read :—

1. *The Amorphous Phase in Metals.* *By* Dr. W. Rosenhain, *F.R.S.*

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2. *The Volatility of Metals.* *By* Professor T. Turner, *M.Sc.*

Considerable attention has been devoted during the past few years to the volatility of metals, especially in vacuo or under reduced pressure, and there are considerable possibilities of practical applications in this direction in future. The boiling-points of metals under various conditions as to pressure and atmosphere have been determined by Greenwood and by Kraft, while Berry, Groves, Nair, and the author have investigated the behaviour of metals and of alloys in vacuo. Distillation in vacuo is specially suitable for volatile and easily oxidisable metals such as sodium, potassium, cadmium, and zinc; lead and bismuth can also be dealt with by similar means. When alloys are heated to suitable temperatures in vacuo, in certain cases quantitative separation can be readily effected as with the zinc-copper, zinc-iron, and tin-lead series. In other cases, as with the copper-nickel, copper-tin, and copper-iron series, neither metal appreciably volatilises. In some instances definite chemical compounds are obtained. The rate of volatilisation is very markedly affected by the pressure, and to some extent also by the nature of the atmosphere employed. A certain definite or critical temperature is required in order to obtain appreciable volatilisation, and this temperature is raised by gaseous pressure. When this critical temperature has been reached the rate is independent of the initial pressure or the nature of the gas, but varies directly as the increase of temperature. In other words, if the initial rate be R and the rate at any higher temperature be R′, then $R' = R + at$. There is an abrupt change in the direction of the temperature curve for equal rates of volatilisation when the pressure reaches 50 mm. of mercury; and at above 80 mm. the curve becomes a straight line. On exhausting it is found that the removal of 1 mm. at from say 2 to 1 mm. pressure produces approximately seventy times the effect of the removal of 1 mm. when starting from any pressure above 50 mm.

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3. *The Structural Changes brought about in certain Alloys by Annealing.* By O. F. Hudson, *M.Sc., A.R.C.S.*

A large number of the useful alloys, particularly those which are rolled, drawn, or otherwise worked, consist of crystals of one kind only—viz. a solid solution. When alloys of this class are annealed, the structural changes that may be observed are:

1. The cored structure usually characteristic of the alloy in the cast state gradually disappears, and the crystals become quite uniform in composition throughout. Structurally the alloy does not now differ from a pure metal, and other structural changes due to annealing are similar in both cases.

2. If the alloy has been worked before it is annealed pronounced crystal growth is observed when the annealing takes place above a certain temperature, which varies with the alloy. In most cases also numerous twinned crystals are seen. In effect the alloy is recrystallised. If the temperature of annealing is raised the crystal growth becomes more pronounced, particularly from certain centres, and a very coarsely crystalline (overheated) metal or alloy may result. It is, however, to be noted that if the annealing is carried out at a suitable temperature a finer structure than the original is obtained.

The recrystallisation of the strained alloy and the disappearance of the 'cores' go on side by side until uniformity of composition is reached.

In the case of alloys consisting of crystals of two or more kinds, those which are malleable are usually composed of crystals of two solid solutions. Generally the chief effect of annealing these alloys is to promote equilibrium between the two phases present. Crystal growth also takes place partly on lines similar to those indicated above and partly by the absorption of the smaller crystals in larger ones of the same kind. In some cases the annealing operation may result in a true recrystallisation. Complete phase and structural equilibrium in some alloys of this class are only attained after very prolonged annealing, and in many instances the alloys as used are in a meta-stable condition.

The decrease in hardness and the lowering of the elastic limit due to the annealing of cold worked metals and alloys are almost complete before crystal growth becomes noticeable, and are apparently unaccompanied by structural changes which can be observed by microscopical examination.

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4. *Diffusion in Solid Solutions.* By Cecil H. Desch, *D.Sc., Ph.D.*

Since the author's report to the Dundee Meeting of the Association, Bruni and Meneghini have succeeded in demonstrating the occurrence of diffusion in a clear, crystalline solid in the case of sodium and potassium chlorides. A mixture of these two salts, heated at 500° or 600°, yields a homogeneous solid solution, the formation of which is recognised by determining the heat of solution in water, which differs from that of a mechanical mixture.

The author's further experiments with metallic alloys show that a sharp boundary is characteristic of diffusion in solids when a chemical compound is formed. An abrupt discontinuity of composition is also observed when one component is removed by solution, as in the dezincification of alloys of copper and zinc.

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5. *Some Phenomena in the Formation of Eutectics.* By F. E. E. Lamplough *and* J. T. Scott.

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6. *The Electrical Conductivities of Sodium Amalgams.* By Ernest Vanstone, *M.Sc.*

Continuing the physico-chemical investigation of sodium amalgams, the author has determined their electrical conductivities when in the solid state. The amalgams were melted and drawn up into a capillary spiral 1 mm. diameter,

and about a metre in length when unwound. Platinum terminals were sealed in at each end of the spiral.

The liquid amalgam in the spiral was allowed to cool slowly and to solidify in the capillary tube, care being taken to preserve the continuity and uniformity of the thread.

The resistance was measured by a potentiometer method. About twenty amalgams have been examined, the composition varying from 0 to 45 atoms per cent. of mercury.

The resistances varied from 0·05 to 0·4 ohm, and the specific conductivities from 18×10^{-4} to $1·9 \times 10^{-4}$. The resistances were measured at a temperature of 15° C. The curve obtained by plotting specific conductivities as ordinates and atomic percentages as abscissæ shows two discontinuities and a minimum point. The breaks occur at 85·5 and 77·9 atoms per cent. of sodium, and the minimum point at 65 per cent. sodium. The thermal diagram has breaks at 85·2, 71·7, and 63·3 per cent. sodium.

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7. *Discussion on the Significance of Optical Properties.*

(i) *Optical Rotatory Powers and Dispersions of the Members of some new Homologous Series. By* R. H. Pickard *and* J. Kenyon.

The authors have synthesised the optically active forms of over 100 compounds belonging to the following ten series: (1) Methyl alkyl carbinols, Me.CHOH.R, (2) esters of methyl ethyl carbinol and normal fatty acids, MeEt.CH.O.COR, (3) esters of methyl *n*-butyl carbinol $Me(C_4H_9)CH.O.COR$, (4) esters of methyl *n*-amyl carbinol $Me(C_5H_{11})CH.O.COR$, (5) esters of methyl *n*-hexyl carbinol $Me(C_6H_{13})CH.O.COR$, (6) esters of methyl *n*-nonyl carbinol $Me(C_9H_{19})$ CH.O.COR, (7) acetates of methyl *n*-alkyl carbinols $Me.R.CH.O.COCH_3$, (8) *n*-dodecoates of the same $Me.R.CH.O.COC_{11}H_{23}$, (9) ethyl alkyl carbinols Et.CHOH.R, (10) *iso*propyl alkyl carbinols $Me_2CHOH.R$. (In each series the 'growing chain' is normal and not branched.)

All these compounds possess simple and closely related constitutions, but no numerical relationship between their rotatory powers has as yet been detected. The optical rotatory and dispersive powers of the compounds show well-marked regularities, which are more or less common to all the series. The most pronounced of these is that due to the special stereochemical configuration of that member of an homologous series in which the growing chain (R or -COR in the above formulæ) contains five carbon atoms.

(ii) *Rotatory Dispersion. By* T. Martin Lowry, *D.Sc.*

Attention was directed to the importance of making measurements of optical rotation over a range of wave-lengths, instead of merely with light of one colour. This is specially necessary in the case of substances, such as derivatives of tartaric acid, in which anomalous rotatory dispersion is known or may be suspected to exist.

After experiments extending over a period of seven years, the methods of measuring rotatory dispersion have been so simplified that they are now within the range of the ordinary advanced student, and should soon become a regular part of the ordinary routine of the laboratory. For many purposes it is sufficient to take readings with the green and violet mercury lines, but sodium and lithium may also be used in order to see whether the curve of rotatory dispersion has the normal form. A still more valuable check is provided by readings taken with the red and green cadmium lines, but these require more complex apparatus and cannot yet be regarded as generally available.

The examination of the optical and magnetic rotatory dispersion of some fifty organic liquids has shown that the curve of rotatory dispersion has an extremely simple form. It can be expressed by the equation

$$\alpha = \frac{k}{\lambda^2 - \lambda_0^2}$$

where k is the 'rotation constant' and λ_0^2 the 'dispersion constant' for the substance. If α is plotted against λ_0^2 the curve is a simple rectangular hyperbola, tending to a limiting value $\alpha = 0$ when $\lambda^2 = \infty$ and to $\alpha = \infty$ when $\lambda^2 = \lambda_0^2$. If $\frac{1}{\alpha}$ is plotted against λ^2 the curve becomes a straight line. In the case of substances, such as ethyl tartrate, which show anomalous rotatory dispersion, two of these terms must be employed, thus:—

$$\alpha = \frac{k_1}{\lambda^2 - \lambda_1^2} - \frac{k_2}{\lambda^2 - \lambda_2^2}.$$

This is in accordance with Biot's view that anomalous rotatory dispersion is produced by the admixture of two substances differing in rotatory dispersive power as well as in the sign of their optical rotations.

(iii) *On Anomalous Rotatory Dispersion. By* L. TSCHUGAEFF.

1. There are three different types of anomalous rotatory dispersion. The anomaly in question may be due: (*a*) To the superposition of two (or more) different kinds of normally dispersing molecules, differing in rotatory dispersive power as well as in the sign of their rotation. This type of anomalous dispersion was first established by Biot. (Ex. mixture of *l*-menthone and *iso*-menthone.) (*b*) To the existence of absorption bands in the spectrum of the active substance, as it has been pointed out by Cotton, Drude, and others. (Cotton's phenomenon.) (Ex. the xanthates and thiourethanes of menthol, borneol, and fenchol.) (*c*) To the *intramolecular* superposition of partial rotations corresponding to several centres of activity of one and the same molecule, as it has been shown first by the author. Experimental evidence in favour of this classification was given.

2. It has been established that the shape of the dispersion curve is largely influenced by constitutive factors, and in the first place by the relative position of the centres of activity and of the chromophor groups within the active molecule, the whole dispersion curve resulting from the superposition of several 'partial' curves. These results were discussed from the point of view of the electronic theory.

3. The influence of the temperature and the nature of the solvent on the rotatory dispersion of the optically active xanthates resembles closely the influence exerted by the same factors on the dispersion of tartaric acid and of its ethereal salts as studied by Winther and others. There must therefore be an intimate analogy in the origin of the anomaly in both cases.

(iv) *Remarks on the Walden Inversion. By* Professor P. F. FRANKLAND, *F.R.S*

(v) *The Rotation of Active Compounds as modified by Temperature, Colour of Light, and Solution in Indifferent Liquids. By* T. S. PATTERSON, *D.Sc., Ph.D.*

Before it can be possible to offer a real explanation of the phenomena of optical activity, attention must be devoted to the lowlier task of trying to understand clearly the main features of the phenomena in question; to study carefully, in fact, what may be termed the morphology of the subject. The variation of rotation with change in the colour of light, with change of solvent, with change of temperature, and perhaps even with change of pressure, must be thoroughly examined.

As regards the last little can be said, but the other three—colour of light used, the nature of the solvent, and the temperature—are of the utmost importance. Even the data available at present seem sufficient to give some idea of the general behaviour of optically active compounds with changes of condition, and this may be summed up into one scheme, as follows:—

It has been found that the rotation of certain active compounds reaches a maximum value at a certain definite temperature. Further, points of inflection

often occur in temperature-rotation curves, sometimes in such as show also a maximum, and by piecing together the evidence collected from an examination of a fair number of optically active substances it seems probable that the variation of the rotation of an active substance with change of temperature may be, and very probably is, a periodic phenomenon, doubtless irregularly periodic—such that several maxima and minima may be expected to occur in the curve representing it. Owing to experimental difficulties, however, it is not possible to trace these curves through any very wide range of temperature.

Now it seems legitimate to assume that a point of maximum rotation indicates that condition of the substance in which one of the groups attached to the asymmetric atom attains to a maximum influence—a singular condition of the substance. When such singular points are found in the curves of condition for a number of fairly closely related compounds it seems reasonable to suppose that the maxima represent the rotations of these different compounds in, at least, fairly similar conditions. The great merit of a maximum rotation is its recognisability and the possibility it affords of tracing some particular state of the compound as the external conditions are varied. Maxima are found at different temperatures for the various members of an homologous series, but the discussion of this field, since it involves the relationship between the rotation and the constitution of a series of active compounds, may be passed over until the variation of rotation of a single active compound with change of external conditions is more fully understood.

Here the first matter to which attention may be directed is that the maximum, in certain cases at any rate, occurs at a different temperature for light of various refrangibilities, whence it would appear that the irregularly periodic temperature-rotation curves are probably retarded on each other; and since the curve for violet light has the greatest amplitude, it follows that these curves cut one another throughout a certain region, and in this region the rotation-dispersion of the substance must necessarily be anomalous. Hence we arrive at once, not, it is true, at an explanation of anomalous rotation-dispersion, but at a reason why anomalous rotation-dispersion should exist at all.

It is doubtful whether any substance will really show normal rotation-dispersion, but if such a substance be found then it seems probable that the temperature-rotation curves for the different colours of light will intersect at a single point, the rotation-dispersion being positive on one side of this point and negative on the other.

Rotation in Solution.—A study of such data as are available appears to show that when such a compound as shows a maximum rotation—for example, ethyl tartrate—is dissolved in some indifferent liquid, this maximum rotation is displaced towards a lower or a higher temperature, as the case may be, with a corresponding alteration in value, solvents differing very much in regard to the displacement which they bring about. Now it is also found that the region in which abnormal rotation-dispersion takes place is shifted, on solution, in a very similar way to that in which the maximum rotation is displaced, and therefore it seems clear that the effect of solution is to displace the whole temperature-rotation curve. It then appears at once why some substances which show abnormal rotation-dispersion at a certain temperature for the homogeneous compound show a normal rotation-dispersion when dissolved in some solvent which considerably alters the rotation. The solvent has the effect of shifting the family of temperature-rotation curves in such a manner as to bring the parts of the curves in the neighbourhood of the maximum into view, and in this neighbourhood the rotation-dispersion appears to be normal.

(vi) *A Partially Corrected Fluor-Quartz Lens System for Spectrum Photography. By* Lieut-Colonel W. GIFFORD.

(vii) *Crystalline-Liquid Substances. By* Dr. J. HULME.

MONDAY, SEPTEMBER 15.

Discussion on the Proper Utilisation of Coal and Fuels derived therefrom.

The discussion was organised with the object of drawing public attention firstly to the many ways in which coal is at present being wasted, and secondly to illustrate what economics have been effected by the co-operation of the chemist.

The discussion was opened by Professor H. E. ARMSTRONG, F.R.S.[1]

Fuel Economy and Low Temperature Carbonisation.
By Dr. G. T. BEILBY, *F.R.S.*

The industrial applications of destructive distillation are most naturally classed under three principal divisions according to the primary product which it is desired to obtain. In the first of these divisions *hard coke* is the primary product; in the second, *illuminating gas*; and in the third, *paraffin wax and oils.* In each case secondary products result from the distillation. In the gas industry, coke, tar, and ammonia have assumed an importance not much inferior to that of the primary product. In coke-making, tar, ammonia, and gas have also assumed an important place, while in the paraffin industry ammonia is of almost equal importance with the primary oil products. But in spite of the increasing importance of the secondary products, the fact remains that in each division of the industry the primary product must continue to be of the first importance. It follows from this that not only in the selection of the raw material to be distilled, but also in the choice of suitable conditions of distillation, the primary product must still receive the chief consideration. In his selection of raw materials the gas-maker has probably the greatest freedom of choice, for illuminating gas can be made from almost any variety of coal or shale. The choice of the coke-maker is more restricted, for he can only use coking coals which will yield a hard and compact form of coke. The choice of the oil-maker is even more restricted; for him the oil shales of Mid and West Lothian supply the only suitable material. In each of these divisions of industry the primary product is being produced to supply the demands of markets which already exist.

This is a truism which is apt to be overlooked by enthusiasts who make revolutionary proposals for the handling of the fuel supplies of the nation. These markets at present absorb the illuminating gas from about seventeen million tons of coal per annum, the hard coke from about sixteen million tons, and the paraffin products from three million tons of shale. In addition, the secondary products from all three divisions find their way into perfectly definite markets. It is clear that if an important revolution in any division of the industry is contemplated, its effect on these existing markets must be carefully considered. If the products are likely to be so altered that new markets will have to be developed for their absorption, this necessity alone may be sufficient to delay the revolutionary change to a very serious extent; at any rate, this possibility must receive serious consideration. The three divisions of the distillation industry are highly organised, self-contained systems, properly adjusted for the supply of certain definite markets, each being sufficiently elastic to respond to any normal development in the demand for its products.

It is now open to us to consider whether the last word has thus been said on the application of the methods of distillation to the raw coal which is used in the United Kingdom. Out of a total home consumption which is in the neighbourhood of 180 million tons, probably not more than about 35 million tons is subjected to distillation in retorts, ovens, and gas producers. Is there any further

[1] See *Journal of Gas Lighting and the Gas World*, September 23, 1913; the *Chemical World*, November 1913.

proportion of this huge total which in the light of the best knowledge of to-day ought to be subjected to the preliminary treatment by distillation before it is used for heating purposes?

One of the largest items of the national consumption is the 35 million tons used for domestic heating. As this is the item which in use produces town smoke in its more unmanageable form, we naturally turn to it as one of the most important fields for reform. Let us first inquire what is actually being done in this direction.

In March of the present year Mr. F. W. Goodenough, in his Cantor Lectures on 'Coal Gas as a Fuel for Domestic Purposes,' gave a most encouraging account of splendid work which is being done by the Gas Light and Coke and the other London gas companies in the introduction of gas for domestic cooking and heating. From these and similar statistics supplied by other cities, we are entitled to conclude that the increasing quantity of coal which is being distilled by the gas companies is going towards the replacement of raw coal by gas and coke, and we are confirmed in the belief that the treatment of coal by distillation is one of the most hopeful directions in which to seek for increased economy and efficiency. This raises again the previous question: are we to rest satisfied that in these admirable achievements of the gas engineer the last word has been spoken from the fuel reformer's point of view?

It is now about eight years since Mr. Parker brought forward a scheme for the production of 'Coalite,' a smokeless domestic fuel made by the distillation of coal at a temperature of 400° to 450° C., in contrast to the gas-retort method of distillation at 900° to 1,000°. Professor Vivian B. Lewes, in supporting this scheme, showed the immense significance of the changes in the proportions as well as in the qualities of the products of distillation which would result from this radical change in the conditions of distillation. The keynote of the scheme from the chemist's point of view was the conservation of the saturated and allied hydrocarbons in the liquid and gaseous distillate, in contrast to the modern gas-works practice in which these hydrocarbons are sacrificed to the production of a large volume of poor gas. This policy of conservation had already found its fullest expression in the shale-oil industry, in which the chief aim had always been to preserve the maximum quantity of paraffin wax in the distillate; but from the gas engineer's point of view Mr. Parker's proposal was regarded as revolutionary and hardly worth serious consideration.

A fairly extensive experience of low-temperature distillation as applied to coal as well as to oil shale led me from the outset to question whether the proposal to distil bituminous coal in long vertical tubes of small diameter would be industrially successful. With the assistance of Mr. H. N. Beilby, and later also of Mr. G. Weller, an experimental inquiry into the possibilities of other methods of distilling coal at a low temperature was carried on in the works of the Cassel Cyanide Company in Glasgow.

By freely exposing small cubes of coal to radiant heat at a temperature of 450° C., it was found that the gases were driven off in about an hour. It seemed reasonable, therefore, to conclude that under practical conditions the time of exposure to heat need not exceed one and a half to two hours. It had been stated in published reports that the time of exposure to heat in the small vertical tubes of Mr. Parker's apparatus was four hours, and at a later stage it was suggested that even this time was not long enough to complete the distillation in the centre of the mass. The object we now set before us was to devise a form of apparatus in which the coal could be exposed to the action of heat in thin layers. The first practical apparatus consisted of a column heated externally in a gas-fired oven, and fitted internally with a series of sloping shelves. Mechanical arrangements were made for feeding the small coal in to the top of the column and for mechanically jolting the shelves so that the coal passed over the whole series from top to bottom in a sheet two to two and a half inches in thickness. The coke was mechanically withdrawn from the bottom of the column. The volatile products of distillation were removed by an exit pipe to suitable condensers and receivers. The performance of this apparatus fully justified our expectations as to the rate at which coal could be exhausted of its gases at 400° to 450°. The time required did not exceed the one and a half hours of our estimate.

The further evolution of the apparatus passed through various stages till a

unit with a capacity of fifteen tons per day was reached. The mechanical difficulties to be overcome as the scale of operations was increased were serious, and even in its present form we are not perfectly satisfied with the apparatus. We are now preparing designs for a further step in which we hope to profit by the experience of the past four years. We are, however, satisfied that the principle of exposing coal to heat in thin layers is sound. We are also satisfied that the production of a mechanically perfect apparatus into which small coal is automatically fed, passed through the distilling zone, and finally passed out through a cooling chamber, only requires a little more patient step-by-step development. It is obvious that an apparatus which could be built in units with a capacity of fifteen to twenty tons per day, which would work automatically, and no part of which need be exposed to a higher temperature than 450° to 500°, ought to provide an exceedingly economical means for the distillation of coal. But I must not omit to tell you the weaknesses as well as the strength of this type of apparatus. It will, in its present form, only work smoothly with non-caking coal. If the coal, on heating, passes through a fusible stage it is apt to stick to the shelves and to accumulate on them. The working then becomes irregular, and eventually stops. Further, the fact that the coal is frequently turned over and dropped from shelf to shelf tends to break it down into small stuff, a good deal of which is no larger than coke breeze. These are both serious, but not fatal, disadvantages.

The greater part of the coke from this unit plant has been used in water-gas producers into which it could be passed while it was still warm and dry. It had thus an initial advantage over the gas-works coke, which usually contains ten to fifteen per cent. of water. The use of the low-temperature coke for water gas-making proved quite satisfactory. Its light nature made it necessary to reduce the pressure of the air blast in the producer, but its freedom from water and its ready inflammability fully compensated for the loss of capacity due to this reduction in the air blast.

A good deal of the low-temperature coke has also been converted into briquettes for domestic fuel. These are easily kindled and kept alight in an ordinary grate, and burn almost without smoke. The experience of numerous householders in Glasgow in the use of this fuel has been most encouraging, and my colleagues are quite satisfied that a steady outlet for a moderately large output could at once be obtained.

The hydrocarbon gases from the unit apparatus have hitherto been passed into the general fuel gas system of the works, but regular laboratory tests have been made of the thermal value, petrol contents, &c. The thermal value of the gas reached the high figure of 850 B.T.U. per cubic foot. The liquid tar has been regularly collected and examined, and the results generally confirm those of other observers.

Our attention has, however, been mainly concentrated on the mechanical development of this method of distillation, and on the production of a domestic or an industrial fuel from the coke. These, in my opinion, are the really fundamental points in the low-temperature scheme. If these are not right then even fancy prices and an unlimited outlet for fuel oil and motor spirit will not save the scheme from failure.

I must repeat that the really significant points are covered by the economic and engineering questions: can an outlet be found for the low-temperature coke? and can a satisfactory apparatus be devised?

The apparatus must be in fairly large units, and it must be automatic, and must work with the smoothness and regularity of the best types of automatic stoking machinery and with the minimum of manual labour or of detailed supervision. The gases and vapours from the distillation must be carefully preserved from loss or damage in the apparatus either through leakage of gas outwards or of air inwards. The necessary heat must be so applied as to cause no deterioration of the material of which the apparatus is constructed, and the heating must, of course, be economical.

Dr. H. G. Colman gave a general account of how far the gas industry was really helping towards the economic use of fuel.

Recent Progress in Gas-Fire Science. By H. JAMES YATES, *F.C.S., M.I.Mech.E.*

Utility being the first motive, the earliest gas fire, being intended to do the work of a coal fire, under conditions of greater convenience, was an imitation of the coal fire. It either occupied the firespace in the ordinary coal grate, or (more frequently) was placed within a similar cavity in a separate stove which was set in front of the discarded coal grate. In either case it consisted of a series of Bunsen burners, arranged along the front bottom bar, the flames of which played or impinged irregularly upon iron frets, wisps of asbestos filaments, or, more generally, perforated balls of refractory material which were intended to suggest the resemblance of a coal fire: these various refractory bodies were heated to low incandescence by immersion in the flames, after the gas had been lit for some time. This contrivance, whatever its convenience, resembled its prototype, the coal fire, in losing much of its heat up the flue, and in yielding only an irregular and inadequate return in the form of radiant heat from the fuel consumed. The improper way in which the flame impinged upon the refractory material also greatly impaired the completeness of combustion, a fact which not only involved waste of fuel, but was liable to occasion an escape of harmful combustion-products into the room, especially when the chimney draught was poor, or the flue outlet of the gas fire badly constructed.

The gas-fire idea having been embodied in these early crude forms, it was gradually realised that on such a basis gas was no match for coal in point of cost, and the question of economising devices came to the front. The manifestly great flue losses led to the heat-economising efforts being all directed towards delaying the escape of the combustion products until they should have communicated as large a proportion as possible of their sensible heat to the body of the stove, to be afterwards transmitted into the apartment in the form of hot-air currents from the stove body. In other words, these early efforts in gas-fire economy aimed at *concentrating on convected heat.*

A shape which these convection devices usually took was the forming of chambers in extended flues within the stove body. The hot combustion products, on passing through these chambers or flues, imparted most of their sensible heat, by conduction through the walls, to currents of cold air from the room, which thus became warmed by passing over the outside of the walls of these chambers, and which issued therefrom as hot-air convection currents into the room through perforations provided for the purpose. But the heat economy thus realised was accompanied by a bad physiological effect, inasmuch as the convection currents leaving the stove were so hot that the dew point of the air of the apartment was unduly raised, and its degree of saturation lowered; the skin and the mucous membranes of the throat and nasal passages of the occupants offering ready sources of moisture, 'dry' sensations, prickling of the skin, and other disagreeable symptoms were complained of. Anyone entering a room so heated could generally 'smell the gas fire,' as it was expressed, partly owing to the cause already mentioned, but perhaps more to the escape of products of combustion into the room, through faulty construction of the stove, and to the burning of dust by contact with the overheated 'convecting' chambers of the stove. Further, owing to the air of the room being hotter than the walls, persons sitting near these, while feeling discomfort owing to the overheated air, might yet experience chilling sensations owing to radiation from their bodies to the cold walls. These drawbacks engendered a widespread prejudice among the public and the medical profession against gas fires.

It was the personal discomfort which such stoves occasioned to myself that led me to take up the matter, and endeavour to devise a new type of gas fire, free from these defects, and in so doing I realised that the only way to remove the popular prejudice was to remove its cause. First of all it was clear that the temperature of the convection currents ought to be reduced, so as to effect a corresponding reduction in the moisture-absorbing capacity of the air of the room. It then occurred to me that the old idea of enhancing the total heating efficiency of the fire by increasing the 'convected' heat effect, in the manner described, was a mischievous one, and the source of much of the trouble; and that the true remedy must be sought for in increasing the 'radiant efficiency' of the fire to the

maximum possible, with consequent decrease in the amount of 'convected' heat.

The known advantage of radiant heat being that it warms the walls, the furniture, and the occupants of the room rather than its atmosphere, the problem was how to increase efficiency in the direction of radiation so as to compensate, both in heating power and in economy, for the reduction in the temperature of the convection currents. The gas fire, which hitherto had been a haphazard evolution from the coal fire, now became the subject of a reasoned and drastic revolution. The convection chambers were dispensed with. The deep fire-chambers became a shallow space in the front of the apparatus, its depth only that of one piece of refractory material. The erratic arrangement of fireclay lumps was superseded by placing two or three such pieces one above the other exactly over the flame so as to form an envelope for it. A little later a more marked step in the evolution of the new radiating fire consisted in joining the two or three fireclay pieces into one, and thus making the firefront consist of a series of hollow fireclay columns (now known as radiants) perforated in a design expressly contrived to promote uniform heating of the column throughout, and with each flame rising into the cavity of its radiant. Care was taken to prevent any impingement on the inner cone of the flame; by this means, and also by using a correctly designed burner, and by making due provision for the proportionment of the gas and air supplies, perfect combustion was ensured. A further important improvement was the dispensing with the cast-iron front bars hitherto used to retain the loose fireclay lumps, and the replacing of these bars by one slight horizontal rod. This arrangement not only left no obstruction in the path of the radiation, but vastly improved the appearance of the fire. The effect of these radical changes has been that the greater proportion of the energy developed by the combustion of the gas around and in contact with the radiants is transmitted into the apartment as radiant heat. This radiant heat quickly makes its warming effect felt by the occupants; yet, inasmuch as it passes through the air without sensibly warming it, the discomforts formerly occasioned by the now discarded 'convection' methods are at an end. The walls and the objects in the room, becoming warmed by absorbed radiant heat, no longer abstract heat from the occupants, and further they gradually warm the air to a moderate degree by convection currents which, being necessarily at a low temperature, do not reproduce the former excessive moisture-absorbing condition in the air.

This gradual warming of the air by contact with the objects in the room naturally cannot begin for some little time after the fire has been lighted—not indeed until the radiant heat of the fire has warmed the walls and furniture. From the outset, however, there is a certain proportion of convected heat from the stove (but at a low temperature, owing to the absence of the old special heating chambers), and this primary or direct low-temperature convection at once begins to gently raise the temperature of the air, thus anticipating—and later on co-operating with—the secondary low-temperature convection from the walls and furniture, in suitably warming—but not overheating—the air. It will thus be seen that although the earlier types of gas fire may have made their heating effect more quickly apparent, yet in the gas fires of to-day the primary convection is also doing its work from the first, though in a less conspicuous and more healthful way. In this way radiation has taken the place of convection as the mode of heat-transference principally aimed at in gas-fire design.

Having thus traced the evolution of the modern gas fire, I come next to that on which the modern gas fire so largely depends—viz., radiation—to the problem of increasing which much research has been devoted. Progress towards higher radiant efficiency in a fire can be measured only when a reliable method of estimating the latter is available. The present accepted method is that adopted by the Joint Committee appointed in 1907 by the Institution of Gas Engineers and the University of Leeds, for the Investigation of Gas Fires; this method, which was originally suggested to the Committee by Professors W. A. Bone and William Stroud, is essentially a radiometer-*cum*-thermopile method. Part of the radiant energy is directly determined (in kilogram centigrade units) by using a radiation calorimeter (or radiometer), and the remainder by means of a thermopile and galvanometer, standardised against the radiometer for each experiment.

Various other methods, both electrical and calorimetrical, have been suggested, but so far as I am aware no authoritative vindication of their reliability has as yet appeared. The most recent suggestion—viz. that of a calorimeter to absorb all the radiation from a fire—fails for one or other of two reasons. In the one case if it be larger than the fire then the water capacity becomes very great, and difficulties occur in ensuring perfect circulation; also heat is lost from the outer surface by convection and radiation. Alternatively, if the instrument be so small as to necessitate its being placed very close to the fire the free access of air to the fire is interfered with, thus upsetting the natural action of the air currents and setting up abnormal conditions.

The testing of gas fires is a much more difficult matter than might be imagined. Considerable experience in heat measurement is called for, and until recently this has not been available in commercial testing laboratories, and even now the number of trained workers who have turned their attention to this branch of research in connection with gas fires is very small. In the absence of such special experience results obtained even by otherwise careful and competent workers are of doubtful value, owing to unsuspected errors in judgment, or to inherent defects in the methods employed.

Ten years ago even the best deep fires did not afford more than 30 to 33 per cent. of the net heat of combustion of the gas in the form of radiant energy. In the effort to secure increased radiation (by which I mean a higher percentage of the heat developed by the combustion of a given amount of gas, delivered as radiant energy) it has been found, as was to be anticipated, that to advance from these low figures to 45 per cent. is much more easy than to make a further increase above 45 per cent. The adoption of the shallow-fire principle, and the dispensing with the front bars, to which I have already referred, was responsible for an increase from 30 per cent. to somewhere about 42 per cent. From this point, by attention to the perfecting of the design and proportion of the burners and backbricks, and—most important of all—that of the radiants, we have been successful in further raising this figure to 48 to 50 per cent., and indeed in some instances to as high as 55 per cent.

From the first gas fires had been made considerably smaller in width than the average coal fire, and when the new shallow-fronted radiation gas fire had been evolved there still remained a general tendency to keep these fires down to a similar narrow width, the impression probably being that inasmuch as gas fires give a more concentrated heat, a smaller firespace was adequate. I became convinced, however, that if gas fires were to take the place of coal fires for heating the largest domestic apartments equally well as the smallest, it would be necessary that gas fires should be made available having a firespace as wide as that of the coal fire. Although this development was simple in appearance, it involved constructional problems which were only solved after considerable experiment; the result has been that gas fires of the new type are now made as wide as 21 inches, fires of that size being capable of heating rooms up to a cubical content of at least 4,000 cubic feet.

The problem of total heating efficiency is, however, not the only one which makers of gas fires have to solve; the equally important question of ventilating effect must also be considered, for a properly constructed gas fire should effectively ventilate as well as heat an apartment. It is obvious that no fire could be considered as hygienically perfect which, when connected with a chimney flue in the ordinary way, and subjected to a moderate chimney draught, allows any products of combustion to escape into the room; but provided that this elementary hygienic requirement is fulfilled, the question of 'hygienic efficiency' resolves itself into the amount of excess air, over and above that required for combustion, which can be drawn up the flue, per cubic foot of gas burned, when the fire is so connected. There is obviously no object served in testing or discussing 'hygienic efficiency' or 'ventilating effect' except in relation to conditions of ordinary chimney draught, because no gas fire ought ever to be used except it be connected with a chimney or flue leading into the outside atmosphere.

It is not difficult to design and proportion the flue vent and the canopy of a gas fire so as to ensure the drawing up the flue of a large volume of air, thus producing good ventilation. The real difficulty is to avoid drawing this large excess of air over the upper portion of the radiants, thus cooling them and

unnecessarily diminishing the radiant efficiency of the fire. In other words, whereas it is comparatively easy to achieve 'ventilation' at the expense of 'radiant efficiency,' a really scientifically constructed fire should ensure an equally good 'ventilation' without sacrifice of radiant efficiency, which, although not so easy, is by no means an impossible matter.

In this connection my own researches have convinced me of the importance of preserving a certain adequate vertical distance between the top of the radiants and the bottom of the canopy of a gas fire, so as to avoid drawing the induced 'ventilating' air over the upper portion of the radiants; experiment has proved that such a constructional feature, combined with an adequate flue vent, ensures a much higher radiant efficiency than another type (in point of fact older, but which it has been recently sought to revive), in which the canopy is brought down to overlap (or nearly so) the top of the radiants. As the relative merits of these two types of construction have recently been under discussion, it may be of interest if I append the results of an investigation of the matter in my own laboratory, which seem to prove conclusively the marked superiority of the first-named type of construction.

To ascertain the total heating efficiency, each type of construction was tested by determining the radiant efficiency, using the Leeds University method, and at the same time determining the amount of heat lost through the chimney flue. The total of these two, deducted from the heat developed by the combustion of the gas, gives the amount of convected heat. It is obviously impossible to estimate directly the convected heat, since the radiant energy also eventually makes itself sensible in this form.

The fires were tested under a series of parallel conditions. In the first case the flue outlets were blocked up; this neutralised any possible cooling action of the flue draught on the radiants. The second test was one with the flue outlets open. In the third the two stoves were connected to a chimney. It ought to be remarked that changes in the meteorological conditions sometimes influence the amount of air withdrawn from the room by a given chimney to a surprising degree.

It will be seen from the figures that the lowering of the canopy, as had been anticipated, resulted in a lowered radiant efficiency and a lowered total heating efficiency, due to the cooling effect exercised on the radiants by the air drawn over them.

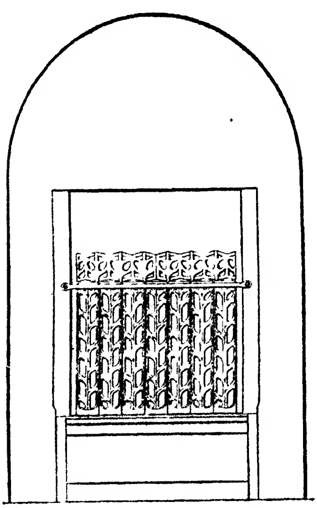


FIG. 1. Canopy well above Radiants.

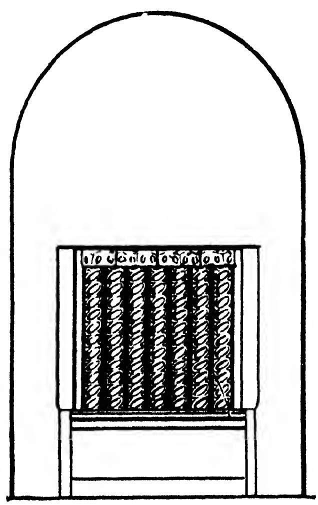


FIG. 2. Canopy brought down to top of Radiants.

Table illustrating different influences of increasing draughts through high and low canopies respectively.

Fire	Consumption at N.T.P. cubic feet per hour	Net Cal. Val. K.C.U. per cubic foot	Net K.C.U. developed by Gas	K.C.U. Radiated	Flue Outlet	Percentage of net heat of combustion		
						Radiated	Removed by Flue Gases	Convected
Canopy well above Radiants, as described	24·15	144 8	3496	1730	Blocked up	49 5	—	—
	24·75	143·6	3553	1710	Open, but not connected to chimney	48·1	27·2	24·7
	25·24	143·3	3617	1730	Connected to chimney	47·8	30·8	21·4
Canopy brought down to top of Radiants	24·73	144·7	3578	1562	Blocked up	43·7	—	—
	24·17	145·7	3522	1373	Open, but not connected to chimney	39 0	36·6	24·4
	23·77	146·9	3493	1223	Connected to chimney	35·0	42·0	23·0

Table showing efficiency results of different sized modern fires attached to a chimney 30 *feet high, the canopy in each case being well above the radiants, as described.*

Fire (width)	Consumption at N.T.P. cubic feet per hour	Net Cal. Val. K.C.U. per cubic foot	Net K.C.U. developed by Gas	K.C.U. Radiated	Per cent. CO_2 in Flue Gases	Temp. of Flue Gases	Percentage of net heat of combustion		
							Radiated	Removed by Flue Gases	Convected
10-in.	25·24	143·3	3617	1730	·90	117° C.	47·8	30·8	21·4
14-in.	34·02	145·5	4950	2490	·80	104° C.	50·3	30·7	19·0
17-in.	42·62	143·2	6102	3003	·93	109° C.	49·2	29·4	21·4
21-in.	52·90	144·8	7661	3903	·77	101° C.	51·0	26·4	22·6

NOTE.—The consumptions shown above are somewhat higher than is necessary in general practice. They were determined by the type with lowered canopy, which required more gas to make the radiants incandescent to the top.

In arriving at the above figures for percentage of heat radiated, it has been thought necessary to make a correction, during the radiation determination, for the convected heat which is absorbed by the radiometer, and which would otherwise figure as radiated heat. This correction is not specifically mentioned in the Report of the Committee which first investigated and used the method at Leeds, and but for this correction the percentage of radiant heat would stand approximately five units higher in each case than the above figures.

The Uses of Gas. *By* Professor WILLIAM A. BONE, *D.Sc., F.R.S.*

1. *Gas Fires.*

Mr. Yates, in his account of the scientific development of the modern gas fire, has referred to the work carried out in my laboratories at Leeds University, under the auspices of the Joint Committee appointed by the University and the Institution of Gas Engineers in 1908, and I may, perhaps, be allowed to add a few supplementary notes to his statements. The work chiefly consisted in the determination of heat balances of gas fires, during the course of which the method for the determination of 'radiant efficiencies' was devised.

The fires were investigated in a room of about 1,000 cubic feet capacity, specially constructed for the purpose, and the flue draught was controlled by means of an electrically driven fan. In view of the prejudice which still exists in the public mind against gas fires, I think it only right to say that very careful tests made on modern fires, of the type described by Mr. Yates, and of different firms' manufacture, gave no positive indication of the presence of any carbonic oxide in the flue products; in one or two of the tests there were suspicions (but no certain proof) of either carbon monoxide or possibly formaldehyde in the flue gases, but in no case did any ever escape from under the canopy into the room. There is no doubt but that the Leeds investigations greatly stimulated the scientific development of the gas fire by the manufacturers themselves; in this Mr. Yates has taken a leading part, and other manufacturers are following his lead in the matter.

In my opinion, no gas fire should ever be used in a living room except it be connected with as effective a chimney draught as would be required by a coal fire, but provided that this condition is fulfilled, the gas fire is both perfectly hygienic and has a comparatively high radiant efficiency.

With regard to what Mr. Yates has said about gas fires and ventilation I entirely agree. If used with an efficient chimney draught, a gas fire will draw up the chimney a considerable amount of excess air over and above that required for the complete combustion of the gas; thus the percentage of carbon dioxide in the flue products of a gas fire operating with an efficient draught need not be more than about 0·8 to 1·3 per cent., whereas without any 'excess air' the proportion would be about 11 per cent. This ventilating effect can be got without material sacrifice of radiant efficiency provided that the design of the fire avoids the obvious cooling effect of drawing the 'excess air' over the top of the radiants; unless this precaution is taken, however, ventilating effect is only produced at a needless sacrifice of radiant efficiency.

With what Mr. Yates has said about the necessity of preserving an adequate distance between the bottom of the canopy and the top of the radiant I also entirely agree, and I can confirm the figures which he has given at the end of his paper by the results of my own independent tests. The conclusions which he has drawn from them concerning the connection between proper design and ventilation are, I think, grounded upon a firm experimental basis, and, although they have been recently controverted in the technical press, they are, I think, unshakable.

2. *Industrial Applications of Coal Gas.*

Turning now to the industrial applications of gaseous fuels it is obvious that the cost of ordinary town's gas must limit its use to comparatively small scale operations, which, however, in the aggregate constitute a large and ever expanding field. In this matter Birmingham with its splendid system of high-pressure gas distribution throughout its industrial areas is showing a lead which other cities might with advantage follow. Gas is supplied through special mains at a pressure of 12 lb. per square inch, and at a price ranging between 1*s.* and 1*s.* 4*d.* per 1,000 cubic feet, according to the amount consumed per quarter.[1] By

[1] The prices are :—

For more than 4 million cubic feet per quarter	1*s.* per 1,000	less 5 per cent.
,, between 3 and 4 ,, ,, ,,	1*s.* 1*d.* ,,	
,, between 2 and 3 ,, ,, ,,	1*s.* 2*d.* ,,	
,, between 1 and 2 ,, ,, ,,	1*s.* 3*d.* ,,	
,, less than 1 ,, ,, ,,	1*s.* 4*d.* ,,	

The quantity of gas sold for manufacturing purposes and motive power during

using, in furnace work, specially designed burners on the injector principle sufficient air can be drawn in with the gas for perfect combustion, with resulting marked economies as compared with the older low-pressure burners. The gas is being used for aluminium and brass melting in crucible furnaces, for the firing of 'glory holes' in glass-works, for annealing furnaces, and other similar purposes. But with the utmost that can be expected from the developments of high-pressure distribution in industrial areas, the uses of town's gas at even 1*s.* per 1,000 cubic feet would still be limited to comparatively small scale operations.

3. *Water Gas.*

For all large scale operations, industrial establishments must rely upon cheap gaseous fuel generated from raw coal or coke on the spot, or in proximity to the works, such as coke-oven gas, blast-furnace gas, producer gas, or water gas. For operations demanding a gas of high calorific intensity, such as steel welding, where regenerative appliances cannot well be adopted, ordinary blue-water gas is admirably suited. With coke at 12*s.* per ton, the cost of making blue-water gas of about 290 B.Th.U.s per cubic foot would be about 4*d.* per 1,000 cubic feet (inclusive of fuel, wages, interest, and depreciation), or, say, equivalent to coal gas at 8*d.* per 1,000. With the recent higher price of coke, the cost would probably be nearer 5*d.* per 1,000 cubic feet, or equivalent to coal gas at 10*d.* per 1,000. A modern water-gas plant will yield about 35 cubic feet of gas at N.T.P. per lb. of carbon charged into the generators, and about 60 per cent. of this carbon will appear in the gas. The ratio of the net calorific value of the gas to that of the coke charged is about 0·70. It should be noted that, despite its much lower 'calorific value,' water gas has a higher 'calorific intensity' than coal gas, and this fact, combined with its lower cost, has established its position in regard to steel welding and the like; the construction of the burners used in such operations is generally faulty and much gas is wasted in consequence.

4. '*Producer Gas.*'

Where a cheap gaseous fuel has to be specially generated *in situ*, the complete gasification of solid fuels by means of a mixed air-steam blast, with or without 'ammonia recovery,' is usually the method adopted. The gas obtained contains some 35 to 45 per cent. of total combustible constituents, and its composition (assuming an ordinary bituminous coal to be the raw fuel) varies between the following wide limits, according to the relative proportions of steam and air in the blast :—[2]

Steam saturation, temp. C.°		50°	85°
Per cent. of composition of the dry gas.	CO_2	2·5	16.0
	CO	30·5	12·0
	H_2	12·3	26·0
	CH_4	3·0	3·0
	N_2	51·7	43·0
Per cent. of total combustibles		45·8	41·0
Net cal. value B.Th.U.s per cubic feet at N.T.P.		169	145
Approximate yield of gas, cubic feet at N.T.P. per ton of coal		133,000	145,000

So high a steam-saturation temperature as 85° permits of a large recovery of the nitrogen of the coal as ammonium sulphate (90 lbs. per ton of coal gasified), but the initial cost of an ammonia recovery plant is still a serious consideration, and the gas is not nearly so well adapted for such operations as steel or glass

the year ending March 31, 1913, was 1,900 million cubic feet at an average price of 1*s.* 3½*d.* per 1,000 cubic feet.

[2] For full information on the chemistry of the gasification and the influence of varying proportions of air and steam in the blast upon chemical composition of the gas and the general efficiency of the process, *vide* Bone and Wheeler, *Journ. Iron and Steel Institute*, 1907, I., 126, and 1908, II., 206.

melting (owing to its larger hydrogen and lower carbon monoxide content) as that produced with a steam-saturation temperature of 50° C. Thus a plant capable of gasifying 250 tons of coal per week would cost about £20,000, but the profit on the ammonium sulphate produced (reckoned as selling at £13 10*s*. per ton) would be about 4*s*. per ton of coal gasified, after providing for labour, acid, stores, and repairs, cost of handling sulphate, and interest and depreciation at 12½ per cent. per annum.

In generating a gas specially for open-hearth steel furnaces, or for glass-melting furnaces, a blast steam saturation temperature of 50° to 55° C. is undoubtedly the best,[3] but under such conditions the amount of ammonia recoverable would be very small. Probably the best steam-saturation temperature, if ammonia recovery be considered in conjunction with suitability of the gas for furnace purposes, would be somewhere about 65° C., which would permit of a recovery of about 45 lbs. of sulphate per ton of coal gasified; moreover, in the ammonia recovery process, the plant for which might be simplified, the gas would be cleaned before delivery to the furnace, an advantage which, in the author's opinion, outweighs the loss of sensible heat involved in cooling the gas.

The design of gas producers has been considerably improved in recent years by the successful introduction of mechanical contrivances for the automatic and continuous removal of ash, such as revolving grates. Claims have been made that the substitution of a revolving for a fixed grate favourably affects the chemical composition of the gas generated, but this is doubtful; the chief advantage derived from the use of such contrivances, apart from labour saving, probably lies in the constant movement imparted to the fuel bed which diminishes the tendency to clinker and facilitates the proper settling down of the charge. Whether the increased capital outlay demanded by the installation of these mechanical devices would be justified by the saving of labour and improved working conditions undoubtedly effected will in each case depend upon the type of fuel used, the amount and composition of the ash, and other local circumstances.

The cost of generating 'ammonia recovery-producer gas of net calorific value 145 B.Th.U s per cubic foot from coal at 15*s*. per ton would probably be about 1*d*. per 1,000 cubic feet, or equivalent to coal gas at 4*d*. per 1,000. Mr. H. A. Humphrey, in a recent paper upon the 'Generation and Distribution of Producer-Gas in South Staffordshire' (the South Staffordshire Mond Gas Co.), said that the average price at which Mond gas, generated at the central station at Dudley Port, Tiplin, and distributed in mains over an area of 123 square miles, is sold to consumers is 1¾*d*. per 1,000 cubic feet, or equivalent to town's gas at 7*d*. per 1,000, a figure which promises well for the future of such schemes in areas of similar industrial concentration.

5. *The Utilisation of Blast-Furnace and Coke-Oven Gases in Steelworks.*

Among recent developments in large scale fuel economics perhaps the newest, and by no means the least important, is the utilisation of blast-furnace and coke-oven gases in iron- and steel-works, both in this country and on the Continent. The long discussion which followed a paper on the subject by Mr. E. Houbaer at the recent meeting of the Iron and Steel Institute at Brussels revealed how much is being done, under scientific guidance, to wipe out the reproach of wastefulness of fuel in this branch of industry. I have had the privilege of long association with the Skinningrove Iron Company, in the Cleveland district, where, under the direction of my relative, Mr. T. C. Hutchinson, much pioneering work has been done in recent years to achieve the utmost fuel economy, and I am indebted to him, as well as to Mr. Houbaer's paper, for most of the information which I propose to bring before you.

In times past—and not so long ago—when the blast-furnace plant was isolated from the coke-ovens on the one hand and the steelworks on the other, coke was manufactured at the pit-head, in the old wasteful bee-hive ovens, and then transported by rail to the blast-furnaces. The pig iron was subsequently converted into steel, and the latter rolled into girders, plates, rails, &c., at a

[3] For a full discussion on this point *vide* a lecture on 'Producer Gas with Special Reference to Steelworks Requirements,' by the Author, in *Journal of West of Scotland Iron and Steel Institute*, 1911, **18**, pp. 144-173.

further expenditure of fuel, and for this purpose raw coal was gasified in producers at the steelworks, and a further quantity sometimes burned under boilers to provide steam power for the rolling mills. Now, for every ton of pig iron produced at the blast furnace, about 1·35 tons of coal had to be coked at the colliery, and a further 0·4 ton of coal had to be gasified in producers during the conversion of the iron into steel in open-hearth furnaces; thus, approximately, 1·75 tons of coal were used per ton of steel ingots produced, not to speak of any further fuel required to drive the rolling mills.

Nowadays, with the concentration of by-product coke-ovens, blast-furnaces, steel furnaces, and rolling mills in one plant, it has become possible to carry through the whole process for the smelting of the iron ore to the finished girder, rail, or plate with the expenditure of no more coal than must be coked for the blast-furnace. And the credit of having achieved this revolution—an industrial romance if ever there was one—must be ascribed to British and Continental metallurgists in equal shares. The following figures will explain how this has come about.

The blast-furnace produces not only iron but, as a valuable by-product, combustible gas, some 168,000 cubic feet (at 15° C. and 760 mm. pressure) per ton of iron. A furnace making 1,000 tons of iron per week (quite a moderate output) will produce every hour approximately a million cubic feet of gas, containing nearly 30 per cent. of carbon monoxide, its chief combustible constituent. Its net calorific value is nearly 100 B.Th.U.s per cubic foot. Some 60 per cent. of the gas is absorbed in generating and heating the blast for the furnace and in leakages, leaving a surplus of 40 per cent. available for purposes outside the blast-furnace plant. In times past, and even to-day in cases where the blast-furnace plant is isolated from the steelworks, this surplus was largely wasted. But where steelworks are adjacent to the smelting plant, as in all the newest installations, this surplus gas, which leaves the furnace at a temperature of about 300° C. and heavily charged with dust, is cooled and cleaned for gas-engine purposes. The power which could thus be generated is more than sufficient to provide for all the mechanical work required both on the steel plant and for the electrically driven rolling mills; the surplus gas not so required may (admixed with coke-oven gas) be used instead of producer-gas for firing the steel furnaces, soaking pits, &c. And even after all these requirements have been fulfilled there may remain a final surplus, convertible into electrical energy for outside uses.

At the Seraing Works of the Cockerill Company, who were the first to build large gas-engines for blast-furnace gas, there are to-day seven blast-furnaces producing some 7,000 tons of pig iron per week; if the whole of the surplus gas were utilised in gas-engines driving electric generators, no less than 28,500 E.H.P. could be generated continuously day and night. This is probably more power than would be required for the steelworks and rolling mills. Accordingly, only 18,500 E.H.P. are being generated, with a thermodynamical efficiency of 23 per cent., the surplus gas being used for heating purposes. So much, then, for the potentialities of blast-furnace gas.

But to provide the coke required at the blast-furnace per ton of pig iron produced, about 1·35 tons of coal must be carbonised in the coke-ovens, and with the most modern by-product ovens of the 'regenerative' type this means a possible recovery of about 30 lb. of ammonium sulphate, benzol, tar, together with an available surplus of 6,000 cubic feet of gas of an average net calorific value of 500 B.Th.U.s per cubic foot. Such a gas is admirably adapted for the enrichment of blast-furnace gas, for the firing of soaking pits, open-hearth furnaces, and the like, thereby displacing altogether the specially generated 'producer-gas' now almost universally employed.

The total thermal value of the combined surpluses of blast-furnace and coke-oven gases per ton of pig iron produced, which may be nowadays considered as available for the steelworks and rolling mills, is somewhat as follows :—

			B.Th.U.s
6,000 cubic feet of	coke-oven gas	$= 6{,}000 \times 500 =$	3 millions
65,000 „	blast-furnace gas	$= 65{,}000 \times 100 =$	$6\frac{1}{2}$ „
		Total =	9·5 millions

This is equivalent to the heat of combustion of about one-third of a ton of coal, which can thus be saved, per ton of pig iron produced.

From figures kindly supplied by Mr. Ernest Bury, M.Sc., manager of the blast-furnaces and coke-ovens, I am in a position to make the following statement about results recently obtained at the Skinningrove Ironworks.

Since October 1911, when the first battery of Otto-Hilgenstock coke-ovens was completed, blast-furnace gas enriched with coke-oven gas up to 130 B.Th.U.s per cubic foot of the mixture, has been regularly supplied to boilers, power house, and soaking pits, and from that time onwards the whole of the steel output of a 275-ton Talbot furnace has been converted into finished steel sections without the employment of any outside fuel. The results for the first half of 1913 were as follows:—

Pig iron made	78,902 tons
Coal carbonised in coke ovens	74,659 „
Steel ingots made	19,520 „
Steel ingots rolled into rails and sections	21,500 „

In addition to the above, successful experiments have been made with running the Talbot furnace on an enriched gas of 180 B.Th.U.s per cubic foot, with excellent results, showing a coal saving of $2\frac{1}{2}$ to 3 cwts. per ton of steel. As soon as the new additional battery of coke-ovens is in operation, it will be possible to heat and roll off 2,000 tons of steel per week, and in addition to contribute an amount of coke-oven gas to the Talbot furnace equal to 100 tons of coal per week. Arrangements are in progress whereby it would shortly be possible to supply any furnace, soaking pit, or power station on the works with either a rich coke-oven gas or a poor blast-furnace gas, or any desired mixture of the two; when these are completed the prophecy made by Mr. T. C. Hutchinson, in his Presidential Address to the Cleveland Institute of Engineers three years ago, 'that the time would come when we shall be taking in ironstone at one end of the works and turning out steel at the other, using only such coal as is required for the coke-ovens,' will be fulfilled.

Dr. R. V. Wheeler dealt with the composition of coal, in particular the volatile constituents.[4]

Dr. R. Lessing spoke on the economics of the smoke nuisance question.

Mr. W. H. Patterson discussed the improvement of combustion and the blending of coals.

A general discussion followed.

The following Paper was then read:—

The Action of an Alkaline Natural Water on Lead.
By J. F. LIVERSEEGE *and* A. W. KNAPP.

The water supply of Birmingham is gathered chiefly in Wales. The water is slightly alkaline: it does not appreciably dissolve lead (absence of 'plumbo-solvency'), but unless treated it corrodes or 'erodes' bright sheet lead. To prevent any danger from this action, a small proportion of powdered chalk is added to the water in Wales. This treated water flows to Birmingham through an aqueduct seventy-three miles long.

Lead Pipes.—For these experiments a series of lead pipes was connected with the supply and analyses of the water made over a period of five years. Hundreds of samples were also taken from consumers' pipes and from lengths of lead pipes closed with corks. For short periods the total lead dissolved from the pipes increased with time, but different lengths of the same pipe showed considerable variation. As a rule a pipe becomes with age less sensitive to the action of the water, but the rate of this change varies greatly with different pipes. Treatment of new pipes with a dilute solution of potassium

[4] See *Journal of the Chemical Society, Trans.*, 1903, 103, 1704-1722.

permanganate gave them a considerable power of resistance to the action of the water.

Sheet Lead.—Many experiments were made on the sheet lead 'erosion' test, and for practical purposes a duration of one day is preferred to the seven or fourteen days suggested by Dr. Houston. We find that erosion is due to the action of oxygen in the presence of water. The amount of lead eroded is affected by the distance from the lead to the water surface, is generally proportional to the area of the surface of the lead exposed, and does not depend on the volume of the water.

With untreated water carbon dioxide up to one per cent. by volume produced little effect on the amount of erosion; when two or more per cent. of carbon dioxide is present erosion no longer occurs, for the liquid remains clear, but lead is dissolved, in amount much less than that removed by erosion. Given sufficient oxygen, the alkalinity of the water is the principal factor determining the amount of erosion. The use of (*a*) *lime* to prevent erosion was not found satisfactory, the presence of three to nine parts per 100,000 of water reduced the erosion, but smaller or larger quantities were of little, if any, use. Four parts per 100,000 of (*b*) *calcium carbonate* gave protection, and as little as two parts per 100,000 of (*c*) *calcium bicarbonate* were sufficient to practically prevent erosion. Filtration through sand had little effect on the action of the water on lead. No evidence was found of a seasonal variation in the action of the water on lead, though the colour and amount of organic matter varied considerably.

TUESDAY, SEPTEMBER 16.

Discussion on Radio-active Elements and the Periodic Law.

(1) *The Radio-Elements and the Periodic Law.* *By* Frederick Soddy, *M.A., F.R.S.*

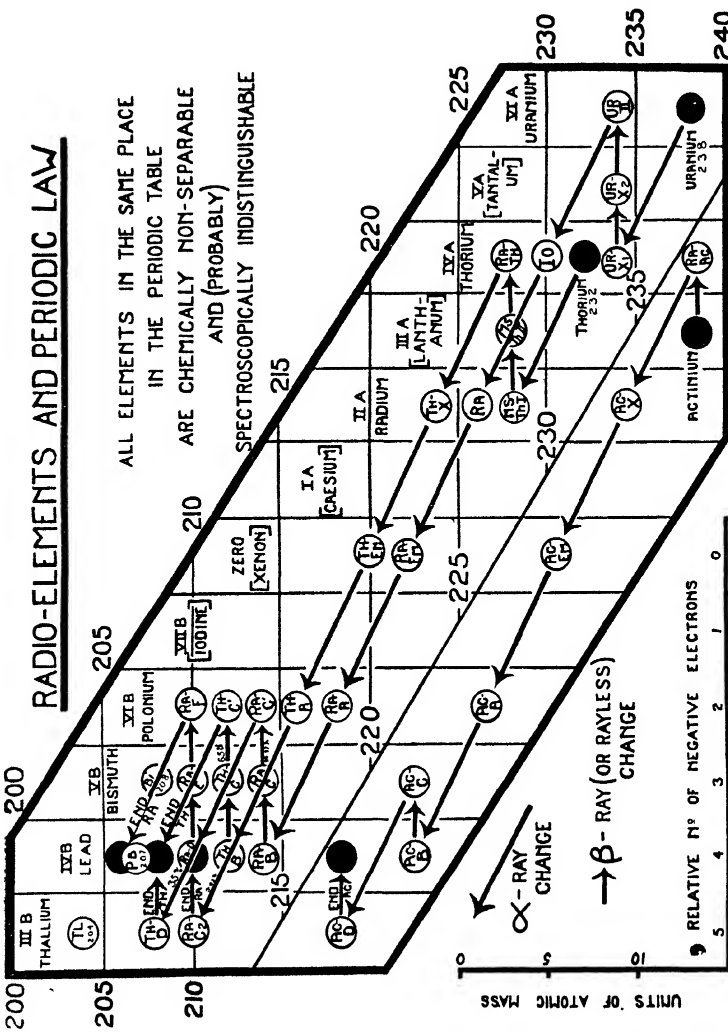
During the present year, 1913, the general law governing the passage through the periodic table of the elements in process of radio-active change has been discovered. As the result it is possible to write the three disintegration series of uranium, thorium, and actinium across the periodic table, so that each member falls into its proper place in the case of the twenty-seven members the chemistry of which is known. For the six members the period of average life of which is too short for the chemical nature to be determinable, and for the five inactive end-products, the chemical nature can be without uncertainty predicted. The general law is that in an α-ray change, when a helium atom carrying two atomic charges of positive electricity is expelled, the element changes its place in the periodic table in the direction of diminishing mass and diminishing group number by two places. In a β-ray change, when a single atomic charge of negative electricity is expelled from the atom as a β-particle, and also in the two changes for which the expulsion of rays has not yet been detected, the element changes its position in the table in the opposite direction by one place.

The generalisation as regards the α-rays was put forward in 1911,[1] but at that time the chemistry of the β-rays giving members, which are mostly short-lived, was not known well enough for anything definite to be said. Fleck in 1911 commenced to make a systematic investigation of the chemically indefinite members, from the point of view adopted in the book referred to, of the existence of chemically identical and non-separable groups of elements. This work occupied two years. Some of the results were communicated to this Section at the Dundee Meeting last year, and they have since been published in the 'Journal of the Chemical Society.'[2] It is important to note that this work was purely experimental, and was done deliberately without any attempt to find the theoretical law, in order that the results might be free from all bias in favour of any par-

[1] Soddy, *Chemistry of the Radio-Elements*, p. 29.
[2] *Proc.*, 1913, 29, 7 and 172; *Trans.*, 1913, 103, 381, and 1052.

ticular view. It would have been easier to speculate first and then to test the speculations, but the opposite course was purposely adopted.

Fleck, in addition to confirming the chemical nature of several of the chemically better known members by careful fractionation methods, had by the beginning of this year succeeded in determining the chemical nature of nine members which had not previously been elucidated. All except two of these



were in the series subsequent to the zero or emanation group, of which members only the two longest lived—polonium and radio-lead—had previously been chemically characterised. At this time A. S. Russell,[3] who knew of Fleck's results, put forward the view that in the β-ray change the position of the element in the periodic table changes by one place, and he was the first to publish a com-

[3] *Chem. News*, January 31, 1913, 107, 49.

plete scheme showing the passage of the radio-elements through the periodic table. His scheme was in certain respects imperfect, and it was followed almost immediately by another by K. Fajans,[4] who put forward the complete law in its present form, and made important and accurate deductions as to the positions occupied by the still unplaced members. Soddy independently arrived at a complete scheme similar to that of Fajans,[5] but which in one respect possibly went somewhat further in regard to the generalisation that all elements falling into the same place in the periodic table are not merely similar in chemical properties, but are chemically identical, non-separable by chemical methods, and probably spectroscopically indistinguishable. From this the definite prediction was made that radium-C_2, thorium-*D*, and actinium-*D* would prove to be non-separable from thallium, and radium *A* from polonium, which Fleck has since established, whilst all the end-products would be non-separable from lead. The scheme, altered slightly to bring it up to date (July 1913), is shown in the accompanying plate.

In all three schemes a new member was indicated in the V A family, as the product of uranium X. This has since been discovered by Fajans and Beer,[6] and confirmed by Fleck.[7] It proves to be a very short-lived substance of period of average life 1·7 minutes, and is called Uranium X_2. Its parent, Uranium X_1, with period 35·5 days, gives only the soft (β) rays, whereas the hard β-rays of Uranium X come from this new product.

This missing member being short-lived disproves the suggestion (Soddy) that it might be a very long-lived and therefore well-defined element (Eka-tantalum), disintegrating dually and producing, in addition to Uranium II. by a β-ray change, actinium by a still undetected α-ray change. This being disproved, the only other possibility to consider as to the still unknown source of actinium is that it is produced in a β-ray or rayless change from radium. On account of the uncertainty of the origin of actinium, and therefore of the atomic weight both of itself and of all its products, the actinium series is shown separately beneath the others in the plate.

The chemical analysis of matter is thus not an ultimate one. It has appeared ultimate hitherto, on account of the impossibility of distinguishing between elements which are chemically identical and non-separable unless these are in the process of change the one into the other. But in that part of the Periodic Table in which the evolution of the elements is still proceeding, each place is seen to be occupied not by one element, but on the average, for the places occupied at all, by no less than four, the atomic weights of which vary over as much as eight units. It is impossible to believe that the same may not be true for the rest of the table, and that each known element may be a group of non-separable elements occupying the same place, the atomic weight not being a real constant, but a mean value, of much less fundamental interest than has been hitherto supposed. Although these advances show that matter is even more complex than chemical analysis alone has been able to reveal, they indicate at the same time that the problem of atomic constitution may be more simple than has been supposed from the lack of simple numerical relations between the atomic weights.

(ii) *The Chemistry of the Radio-Elements.* *By* Alexander Fleck, *B.Sc.*

Since last year's meeting at Dundee, when the chemistry of three short-lived radio-elements was described, the study has been continued, and the chemical nature of eleven additional radio-elements has been worked out experimentally. In each of these cases, with the one exception of Uranium-X_2, the chemistry of the substance may be summed up by saying that it has properties identical in all respects with those of some already known element. In general the experimental methods were divided into two parts: First, determining what element the short-lived radio-element most resembled, and, second, determining, usually

[4] *Phys. Zeit.*, February 15, 1913, 14, 131 and 136.
[5] *Chem. News*, February 28, 1913, 107, 97.
[6] *Naturwissenschaften*, April 4, 1913. [7] *Phil. Mag.*

by fractional methods, whether the radio-element was separable from the ordinary element. As in most cases the already known element was a common one, the non-separability of the two could be shown by using a β-ray electroscope for the relative measurement of the radio-elements, whilst the ordinary element was estimated by some gravimetric process.

In one or two cases, as in that of radium-A and polonium and mesothorium-2 and actinium, where both elements were radio-active and present in unweighable quantities, special electroscopic methods of measurement were devised.

The results of the work show that :—

1. Uranium-X and radio-actinium are chemically identical with thorium.
2. Mesothorium-2 is chemically identical with actinium.
3. Radium-*A* is chemically identical with polonium.
4. Radium-*C*, thorium-*C*, actinium-*C*, and radium-*E* are chemically identical with bismuth.
5. Radium-*B*, thorium-*B*, and actinium-*B* are chemically identical with lead.
6. Thorium-*D* and actinium-*D* are chemically identical with thallium.

In the cases in which the inseparable elements are common elements these latter have all atomic weights above 200, and occupy one or other of the last twelve places of the periodic table.

(iii) *Radio-Elements as Indicators in Chemistry and Physics.* *By* G. VON HEVESY, *Ph.D.*

By means of an α-ray electroscope of ordinary sensitiveness it is possible to measure accurately as small a quantity as 10^{-17} grm. of a radioactive substance having a half-value period of one hour. The extraordinary simplicity and at the same time sensitiveness with which it is possible to measure these extremely small quantities of radioactive bodies makes them of the greatest use not only in studying substances in great dilution but also as indicators of physical and chemical processes.

Radioactive indicators may be conveniently divided into two principal groups. To the first group belong those whose use as indicators depends only on their physical properties, and not on their chemical properties. Some examples of the use of radioactive indicators of this kind are the following :—

It is only necessary to know that the radio-elements composing the active deposits are metals in order to test the formula of Arrhenius connecting the variation of velocity of solution of metals in acids with the temperature. This has been lately carried out by Miss Ramstedt.

It is known from the kinetic theory that the concentration of a solution varies with time, and this problem, which could not be attacked by ordinary methods, has been made experimentally feasible by the use of radioactive bodies as indicators. (Svedberg, Smoluchowski.)

The existence of colloidal solutions of radio-elements has been lately established by Paneth and Godlewski, and experiments have been undertaken on the formation and precipitation of these colloids using radioactive indicators.

The emanations, the only gaseous radio-elements, have been employed to establish the validity of the gas laws, especially that of Henry's law for extremely small partial pressures. (Bruhat, Boyle.)

Fick's Diffusion Law has also been shown to hold accurately for bodies in infinitely small concentration by making use of radioactive substances.

It is often a question of practical interest to the chemist to know how often it is necessary to wash out a pipette or a beaker in order to remove the last trace of the solution it had contained. This problem can be investigated with extreme ease when radioactive indicators are used.

The fact, however, that most radio-elements are throughout in all chemical properties exactly similar to some of the common elements (for instance, radium D and thorium B are non-separable from lead, thorium C and radium E from bismuth, &c.) allows these bodies to be used chemically as indicators of the bodies from which they are known to be non-separable. Radium E can be used as an indicator for bismuth, radium D for lead, &c.

If one mg. of lead is mixed with a quantity of radium D which gives 10,000 units of activity in an electroscope, one-millionth part of this mixture is easily detectable by the radioactivity of radium D. In this way 10^{-6} mg. lead is quantitatively determinable.

By this method also the solubility of the difficultly soluble salts of lead such as the chromate and the sulphide has been determined. Further, the amount of lead chloride entrained by a precipitate of silver chloride after washing the latter thoroughly with water is measurable.

Experiments on the electrochemical behaviour of small quantities of lead and bismuth have been begun. By means of these indicators a study may be made of the electrochemical behaviour of these metals for electrode potentials lying below the decomposition voltage, a problem which could not be investigated by any other means.

Of especial use are the indicators for investigating the diffusion and mobility of ions in extremely small concentration, from which results we obtain information concerning the behaviour and the hydration of ions in very dilute concentration. Datas are already available on the diffusion rate of lead salts down to a normality of 10^{-14}.

The following Papers were then read:—

Physical Division.

1. (*a*) *Neutral Salt Action.* (*b*) *Solubility and Distribution.* *By* Dr. B. de Szyszkowski.

2. *Some Suggestions regarding the Nomenclature of Optical Activity.* *By* Dr. T. S. Patterson.

3. *The Hydrogen Ion Concentration of the Sea and the Alkali Carbon Dioxide Equilibrium.* *By* Dr. Prideaux.

Metallurgical Division.

4. *The System Copper-Oxygen.* *By* F. D. Farrow.

This paper presented in a concise form the results of the work on the melting-points and dissociation pressures of the system copper-oxygen, obtained by Heyn, Wöhler, and by Slade and Farrow. Heyn has obtained melting-points of mixtures containing up to 1 per cent. of oxygen. He finds a eutectic point with an oxygen content of 0·39 per cent. at 1065° C., while the mixture containing 1 per cent. of oxygen melts at 1167° C.

Slade and Farrow have shown that mixtures containing between about 2·3 and 10·3 per cent. of oxygen when heated above 1195° C. melt and form two liquid layers, the upper of which is richer in oxygen than the lower. The composition of these layers is for all temperatures investigated about 2·3 per cent. of oxygen for the lower and about 10·3 per cent. for the upper. The compositions do not appear to approach each other with rising temperature. By extrapolating over a short distance the authors place the melting-point of cuprous oxide (11·26 per cent. of O) at 1210° C.

The same authors have investigated systems whose composition lies between those of cuprous and of cupric oxide. They find two melting-point curves which intersect at about 1060° C. The eutectic mixture corresponding to this has a composition of 14·8 per cent. of oxygen. The melting-point of cupric oxide is found not to have been attained at a temperature of 1148° C., at which temperature the dissociation pressure of the oxide exceeds 2½ atmospheres.

Wöhler has determined the dissociation pressures of cupric oxide when heated. He has shown that solid solutions of cuprous oxide in cupric oxide are formed. His values therefore are somewhat lower than the highest dissociation pressures obtainable.

Slade and Farrow have determined the dissociation pressures of cuprous oxide at temperatures and under conditions at which the mixture of two liquid phases mentioned above must necessarily have been present. These pressures are given in the subjoined table as points on the experimental curve *c g*.

From the sources mentioned the data have been collected and used to construct a temperature-composition and a temperature-pressure diagram which are attached to the paper.

Table of numerical values of the data represented by the chief points on the diagrams.

Name	Temperature Centigrade	Composition =oxygen content per cent.	Pressure	Explanation
Points				
a	1084	0·0	—	M.P. of pure Cu
b	1065	0·39	—	Cu, Cu_2O eutectic
c	1195	2·26	—	Invariant point. Phases present: Solid Cu_2O, liquid I. Liquid II. Gas.
d	1210	11·16	—	M.P. of pure Cu_2O
e	c. 1060	c. 14·8	c. 460 mm.	Cu_2O, CuO eutectic
f	?c. 1240	20·10	? 20 atm.	M.P. pure CuO
Curves				
m e	960	—	50 mm.	Wohler's curve of CuO dissociation pressure
	1050	—	314 mm.	
	1070	—	458 mm.	
c g	1205	—	4 mm.	Slade *v.* Farrow's curve of dissociation pressure of the two liquid phases of the Cu_2O, Cu mixture.
	1240	—	10 mm.	
	1260	—	12 mm.	
	1324	—	25 mm.	

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5. *Equilibria of Reduction of Oxides by Carbon.*
By R. E. Slade *and* G. I. Higson.

The equilibrium pressures obtained when certain oxides are reduced by carbon have been determined.

The reaction which takes place is of the type

$$MO + C \rightleftarrows CO + M$$

where M denotes two equivalents of one of the following substances: V, Ta, Cr, B, Mn, Sn.

In some cases a carbide is formed. This reaction is represented by the equation—

$$2MO + 3C \rightleftarrows M_2C + 2CO.$$

In the experimental method employed there was always an excess of the free metal present. In either case there are three components, M, C, and O, and four phases, CO, M, MO, and either C or M_2C. Therefore, there is one degree of freedom of the system. At each temperature there is a definite pressure of CO.

The substance M was heated in an unglazed porcelain boat *in vacuo*, in the

furnace already described by one of us.[1] CO was admitted and reacted with the substance until the pressure had fallen to that of equilibrium. Some CO was then pumped out and the equilibrium attained from the other side.

The upper limit of temperature in some cases was determined by the volatility of the metal, the lower limit of temperature is 800°-900° when the reaction

$$2CO \rightarrow CO_2 + C$$

begins to take place to some extent.

Summary of experimental results :—

	Temperature	Pressure
Vanadium	1340°	1·5 mm.
Tantalum	1270°	<0·1 mm.
Chromium	1292°	6·2 mm.
	1339°	9·2 mm.
Tin	750°	>760 mm.
Tin in presence of SiO_2	753°	670 mm.

The values of the equilibrium pressures have also been calculated on the basis of the Nernst heat theorem, and the heats of reaction calculated from the equilibrium pressures when the heats of reaction were not previously known.

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6. *The Dissociation Pressures of some Nitrides.* *By* R. E. Slade *and* G. I. Higson.

The dissociation pressures of the nitrides of vanadium, tantalum, and boron have been investigated.

The substance was heated in an unglazed porcelain boat *in vacuo*, in the furnace previously described by one of us.[1] Nitrogen was admitted and was absorbed by the substance to form nitride until the dissociation pressure was attained. Some nitrogen was then pumped off and the equilibrium attained from the other side.

Summary of experimental results :—

	Temperature	Pressure
Vanadium	1203°	Not greater than 0·2 mm.
	1271°	Not greater than 1·5 mm.
Tantalum	1170°	0·4 mm.
Boron	1222°	Not greater than 9·4 mm.

The results were discussed from the point of view of the Nernst heat theorem.

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7. *The Solution of Gases in Metals.* *By* Dr. A. Holt.

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8. *A Study of the Degradation or Enhancement of Quality of Commercial Copper by the Presence of Impurities.* *By* Frederick Johnson, *M.Sc.*

In this paper the author surveyed the facts and theories which have been brought to light of late years by modern scientific investigation of the influence of traces of impurities upon the chemical, physical, and mechanical properties of copper. Much of the mystery formerly attaching to defects during manufacture and failures in service has been cleared up, to the benefit alike of the manufacturer and the user. Ancient and modern prejudice against the presence of impurities such as oxygen and arsenic has been shown to have no foundation in fact when certain uses of the copper are considered.

[1] *Proceedings of the Royal Society*, 1912, vol. 87, A, p. 519.

The knowledge of metallurgical testing and analysis was shown to be indispensable when the varying composition of commercial brands of crude copper and the multitudinous uses to which refined copper is put are taken into consideration.

Manufacturers should never lose sight of such fundamental considerations as the following :—

1. To what degree the various impurities may be eliminated during refining operations.

2. To what specifications (however imperfect such specifications may be) the resulting changes may have to conform.

3. To what extent impurities may mutually react to the improvement or detriment of the resulting material.

The author has given special attention to the influences of oxygen and arsenic, whilst bismuth, lead, nickel, antimony, silicon, iron, phosphorus, manganese, &c., are all dealt with in turn.

The evidence of the microscope was called largely into requisition and the importance of various kinds of testing was emphasised.

SECTION C.—GEOLOGY.

PRESIDENT OF THE SECTION.—PROFESSOR E. J. GARWOOD, M.A.

THURSDAY, SEPTEMBER 11.

The President delivered the following Address:—

ON the last occasion when members of the British Association met in Birmingham, in 1886, this Section was under the able presidency of my friend Professor T. G. Bonney, who at that time occupied the chair of Geology in University College, London. Fifteen years later I succeeded him on his retirement from that post, and to-day I succeed him as President of this Section, at the fifth meeting of the Association at Birmingham; once more I feel the same diffidence in following him in Birmingham as I did in London.

In his Address in 1886 Professor Bonney discussed the 'Application of Microscopic Analysis to Discovering the Physical Geography of Bygone Ages.' Strangely enough, this title might apply almost equally well to the subject of my Address to-day; but whereas Professor Bonney employed for his purpose the evidence obtained from observations on mechanical sediments, I propose to deal with certain organically formed deposits with the same object.

More than twenty years ago, whilst engaged in the study of the Lower Carboniferous rocks of Westmorland, I noticed the occurrence of certain small concretionary nodules of very compact texture, in the dolomites near the base of the succession in the neighbourhood of Shap.

Shortly afterwards, when examining the Bernician rocks of Northumberland, I again met with similar compact nodular structures. It was obvious, however, even at that time, that the Northumberland specimens occurred here at a much higher horizon than those which I had observed in Westmorland.

More recently, whilst studying the lithological characters of the Lower Carboniferous rocks of the North of England and the Border country, I have been still further impressed by the abundance of these nodular structures at several horizons, and the large tracts of country over which they extend. An examination of these nodules in thin sections showed their obvious organic character, and I was at first inclined to refer them to the Stromatoporoids. Dr. G. J. Hinde, who was kind enough to examine my specimens from the Shap district, reported, however, that they were probably not Stromatoporoids, but Calcareous Algæ, and referred me to the descriptions of *Solenopora* published by the late Professor Nicholson and Dr. Brown.

Since then I have examined a large number of nodules collected from different horizons in the Lower Carboniferous rocks of Britain and Belgium; and the examination has convinced me that the remains of Calcareous Algæ play a very much more important part in the formation of these rocks than has hitherto been generally realised.

The majority of geologists in this country have been slow to recognise the

importance of these interesting organisms and, with the notable exception of Sir Archibald Geikie's text-book, we find but scant allusion in English geological works of reference to the important part played by Calcareous Algæ in the formation of limestone deposits.[1]

From the more strictly botanical standpoint, however, we are indebted to Professor Seward for an admirable account of the forms recognised as belonging to this group up to the date of the publication of his text-book on Fossil Plants in 1898; while in an article in *Science Progress* in 1894, he has also dealt with their importance from a geological point of view.

Since these publications, not only have several new and important genera been discovered in this country and abroad, but the forms previously known have also been found to have a very much wider geological and geographical range than was formerly suspected; and I venture to hope that a summary of our knowledge of the part which they play as rock builders more especially in British Palæozoic deposits, will serve to stimulate an interest in these somewhat neglected organisms among geological workers in this country.

Previous to 1894, in which year Dr. Brown first referred *Solenopora* to the Nullipores, we meet with little, if any, reference to the occurrence of fossil Calcareous Algæ in British deposits.

Indeed, in this country the subject has attracted but few workers, and they can almost be counted on the fingers of one hand. When we have mentioned the late Professor H. A. Nicholson and Mr. Etheridge, jun., Mr. E. Wethered, Dr. Brown, Dr. Hinde, and Professor Seward, we have practically exhausted the list of those who have contributed to our knowledge of the subject. To these we may add the name of Mrs. Robert Gray, whose magnificent collection of fossils from the Ordovician rocks of the Girvan district has always been freely placed at the disposal of geological workers, and has furnished numerous examples of these organisms to Professor Nicholson and the officers of the Geological Survey.

It was Nicholson and Wethered who first recognised the important part played in the formation of limestones, by certain organisms, which, though referred at the time to the animal kingdom, are now generally considered to represent the remains of Calcareous Algæ.

The presence of these organisms in a fossil state, especially in the older geological formations, has only been recognised in comparatively recent years; though it was suggested as long ago as 1844 by Forchhammer[2] that fucoids, by abstracting lime from sea water, probably contributed to the formation of Palæozoic deposits. When we remember that it was not until the researches of Phillipi were published in 1837 that certain calcareous deposits were discovered to be directly due to the growth of living forms of lime-secreting algæ, it is not surprising that, only in comparatively recent years, has the importance of the fossil forms as rock-builders in past geological formations been recognised.

The original genera established by Phillipi—namely, *Lithothamnion* and *Lithophyllum*—are now known to have a wide distribution in the present seas, and it is therefore natural that it should be examples of these genera which were the first to be recognised in a fossil state in Tertiary and, subsequently in Upper Cretaceous rocks.

Thus in 1858, Professor Unger of Vienna showed the important part played by *Lithothamnion* in the constitution of the Leithakalk of the Vienna Basin, while seven years later, Rosanoff contributed further to our knowledge of Tertiary forms. In 1871 Gümbel published his monograph on the 'so-called Nullipores found in limestone rocks,' with special reference to the *Lithoamnion* deposits of the Danian or Maestricht beds. Since then *Lithothamnion* has also been reported from Jurassic rocks, and even from beds of Triassic age, though in the latter case, at all events, the reference to this genus appears to require confirmation. In this country the recognition of fossil Calcareous Algæ dates from a considerably later period. It will be best first to review the chief genera which appear to be referable to the Calcareous Algæ, and afterwards to discuss the part they play as rock-builders in the different geological formations.

[1] Geikie, *Text-book of Geology*, 4th ed., vol. i., pp. 605 and 611. 1903.
[2] *British Association Report*, 1844, p. 155.

Two important genera are usually recognised at the present day as occurring in the British Palæozoic and Mesozoic rocks—namely, *Solenopora* and *Girvanella* —and to these I propose to add Wethered's genus, *Mitcheldeania*, together with certain new forms from the Carboniferous rocks of the North of England, which appear also to be referable to this group.

Solenopora.

This genus was first created by Dybowski in 1877 for the reception of an obscure organism, from the Ordovician rocks of Esthonia, which he described under the name *Solenopora spongioides* and regarded as referable to the Monticuliporoids.

Nicholson and Etheridge[3] in 1885 showed that the form described by Billings in 1861 as *Stromatopora compacta*, from the Black River limestones of North America, was in reality Dybowski's genus *Solenopora*, and in all probability was specifically identical with the form from Esthonia. Moreover, they considered that the organism they themselves had described under the name of *Tetradium Peachii* in 1877, from the Ordovician rocks of Girvan, was also referable to Billings's species, though perhaps a varietal form. Thus *Solenopora compacta* was shown to have a very wide distribution in Ordovician times.

Nicholson in 1888 defined the genus as including 'Calcareous organisms which present themselves in masses of varying form and irregular shape, composed wholly of radiating capillary tubes arranged in concentric strata. The tubes are in direct contact, and no coenenchyma or interstitial tissue is present. The tubes are thin-walled, irregular in form, often with undulated or wrinkled walls, without mural pores, and furnished with more or fewer transverse partitions or tabulæ.'[4]

At that time Nicholson still considered *Solenopora* as representing a curious extinct hydrozoan, though already, in 1885, Nicholson and Etheridge had discussed its possible relationship to the Calcareous Algæ. They did not, however, consider that there was sufficient evidence for concluding that the true structure of *Solenopora* was cellular, but added: 'If evidence can be obtained proving decisively the existence of a cellular structure in *Solenopora*, then the reference of the genus to the Calcareous Algæ would follow as a matter of course.'[5]

In 1894 Dr. A. Brown[6] investigated more fully the material which had been placed in his hands by Professor Nicholson, and gave an account of all the forms referable to *Solenopora* known at that date.

To those already recorded, he added descriptions of four new species from the Ordovician rocks—namely, *S. lithothamnioides*, *S. fusiformis*, *S. nigra*, and *S. dendriformis*, the two latter being from the Ordovician rocks of Esthonia.

In the same paper also he published for the first time a description of a new species of *Solenopora* from the Jurassic rocks of Britain, to which Nicholson, in manuscript, had already assigned the name of *S. jurassica*, though, as will be pointed out later, it is probable that two distinct forms were included by Brown under this name.

This record of *Solenopora* from the lower Oolites of Britain extended the known range of this genus, for the first time, well into the Jurassic period. In this paper Brown first brought forward good evidence for removing *Solenopora* from the animal kingdom, and placing it among the Coralline Algæ, and Professor Seward, in Volume I. of his work on Fossil Plants, considers that there are good reasons for accepting this conclusion.

At the time of the publication of Dr. Brown's paper, and for some years afterwards, the only formations in which *Solenopora* was known to occur were the Upper Ordovician and the lower Oolites. The diversity of forms, however, met with in the Ordovician rocks, and their widespread distribution, pointed to the probability of the existence of an ancestral form in the older rocks, while it also appeared incredible that no specimens of intervening forms should

[3] *Geol. Mag.*, 1885, Dec. III., vol. II., p. 529.
[4] *Geol. Mag.*, 1888, Dec. III., vol. V., p. 19.
[5] *Op. cit.* ([3]).
[6] *Geol. Mag.*, 1894, Dec. IV., vol. I., p. 145 *et seq.*

have been preserved in the rocks representing the great time-gap between the Ordovician and Jurassic formations.

In this connection Professor Seward remarks[7]: 'It is reasonable to prophesy that further researches into the structure of ancient limestones will considerably extend our knowledge of the geological and botanical history of the Corallinaceæ.' This prophecy has been amply fulfilled, especially as regards this particular genus, and recent discoveries go far towards filling the previously existing gaps in our knowledge of the vertical distribution of this interesting genus.

Thus the recent detection in the lowest Cambrian rocks of the Antarctic Continent of a form which appears to be referable to this genus enables us to trace the ancestry of *Solenopora* back almost to the earliest rocks in which fossils have yet been discovered, while the gap in the succession which previously existed between the Ordovician and Jurassic forms was decreased by the description in 1908 by Professor Rothpletz of a new species *Solenopora gotlandica*, from the Silurian rocks of Faröe Islands in Gotland.[8] A large number of deposits, however, still remained, between the Gotlandian and lower Jurassic beds, from which no example of *Solenopora* had so far been recorded.

The identification, therefore, a few years ago, by Dr. G. J. Hinde, of examples of this genus from among the nodules I had collected from the Shap dolomites, is of considerable interest, as the presence of *Solenopora* in the lower Carboniferous rocks of this country materially decreases the gap in our knowledge of the succession of forms belonging to this genus, which had previously existed.

Girvanella.

This organism, which is now known to be widely distributed in the Palæozoic and Mesozoic rocks of this country, was originally described in 1878 by Nicholson and Etheridge, jun., from the Ordovician rocks of the Girvan district. The genus was established to include certain small nodular structures composed of a felted mass of interlacing tubes, having a width of 10 and 18 μ, the cells being typically simple, imperforate tubes without visible internal partitions. The geno-type, *G. problematica*, was, however, at that time referred to the Rhizopods and regarded as related to the arenaceous foraminifera.[9] In 1888 Nicholson, in redescribing this genus in the *Geological Magazine*, compares *Girvanella* with the recent form *Syringammina fragillissima* of Brady.

More recently Mr. Wethered has shown that an intimate association frequently exists between *Girvanella* tubes and oolitic structure, and he has described several new species of *Girvanella*, from the Palæozoic rocks and also from certain Jurassic limestones.

The reference of *Girvanella* to the Calcareous Algæ, though not yet supported by incontestable evidence, has been advocated by several writers in recent years. Even as long ago as 1887, Bornemann, in describing examples of *Siphonema* (*Girvanella* Nich.), which he had discovered in the Cambrian rocks of the Island of Sardinia, suggested that this organism might belong to the Calcareous Algæ.

In 1891 Rothpletz[10] noticed that some of the specimens of *Girvanella* which he had examined were characterised by dichotomous branching of the tubes; on this account he removed the genus from the Rhizopods to the Calcareous Algæ, placing it provisionally among the Codiaceæ. Three years later Dr. A. Brown, in summing up the evidence in favour of the inclusion of *Solenopora* among the Nullipores, expressed the opinion that *Girvanella* might ultimately come to be regarded as referable to the Siphoneæ Verticillatæ.

In 1898, however, this genus was still only doubtfully placed with the Calcareous Algæ, for Seward, in his work on fossil plants,[11] remarks: 'The nature of *Girvanella*, and still more its exact position in the organic world, is quite uncertain. . . . We must be content for the present to leave its precise nature

[7] *Fossil Plants*, vol. I., p. 190, 1898.

[8] *Kungl. Svenska. Vets. akad. Handl.* Bd. 43, No. 5, 1908, p. 14, pl. iv., pp. 1–5.

[9] *Silurian Fossils in the Girvan District*, 1878, p. 23.

[10] *Zeitsch. d. D. Geol. Gesell.*, 1891.

[11] *Op. cit.* (7), p. 125.

still *sub judice* and, while regarding it as probably an alga, we may venture to consider it more fittingly discussed among the Schizophyta than elsewhere.'

In 1908, however, Rothpletz, in discussing the relationship of *Spherocodium* and *Girvanella*, reaffirms his opinion that the latter must be referred to the Codiaceæ.[12]

Mitcheldeania.

This genus was first described by Mr. Edward Wethered from the Lower Carboniferous beds of the Forest of Dean[13] under the name of *Mitcheldeania Nicholsoni*; it was referred by him to the *Hydractinidæ*, and considered to be allied to the *Stromatoporoids*. The figure accompanying this paper unfortunately fails to show any of the characters of the organism, but a better figure of the same species was subsequently published in the Proceedings of the Cotteswold Naturalists' Field Club.[14]

In 1888 Prof. H. A. Nicholson[15] published in the *Geological Magazine* figures and descriptions of a new species of this genus (*M. gregaria*), and redefined the genus as having 'the form of small, rounded or oval calcareous masses made up of capillary tubes of an oval or circular shape, which radiate from a central point or points, and are intermixed with an interstitial tissue of very much more minute branching tubuli.' He compares the larger tubes to zooidal tubes, and states that they 'communicate with one another by means of large, irregularly placed foramina resembling "the mural pores" of the *Favositidæ*, and they occasionally exhibit a few irregular transverse partitions or tubulæ.'

With regard to the systematic position of this genus, Nicholson remarks: 'In spite of the extreme minuteness of its tissues, the genus *Mitcheldeania* may, I think, be referred with tolerable certainty to the *Cœlenterata* . . . its closest affinities seem to be with the Hydrocorallines . . . on the other hand all the known hydrocorallines possess zooidal tubes which are enormously larger than those of *Mitcheldeania*; and there are other morphological features in the latter genus which would preclude its being actually placed, with our present knowledge, in the group of the *Hydrocorallinæ*.'

Since this description by Prof. Nicholson, no further account of this organism, so far as I am aware, has been published, and its reference to the *Hydrozoa* rests on Prof. Nicholson's description.

During the past few years I have collected a large amount of material from both of the type localities from which Mr. Wethered and Prof. Nicholson obtained their specimens, and an examination of this material has impressed me strongly with the resemblance of *Mitcheldeania* to forms such as *Solenopora* and *Girvanella*, now usually classed among the Calcareous Algæ. In the rocks in which it occurs *Mitcheldeania* appears as rounded and lobulate nodules, breaking with porcellanous fracture and showing concentric structure on weathered surfaces, very similar to nodules of *Solenopora*; while under the microscope the branching character of the tubules and their comparatively minute size appear to separate them from the Monticuliporoids. Prof. Nicholson appears to rely on the presence of pores, which he thought he observed in the walls of both the larger and finer tubes, for the inclusion of this genus with the Hydrocorallines, though he appeared to be doubtful about their occurrence in the interstitial tubuli. An examination of a large number of slides has failed to convince me of the presence of pores, even in the larger 'zooidal tubes.' The large 'oval or circular' apertures noticed by Nicholson appear to be either elbows in the undulating tubes cut across where these bend away from the plane of the section, or places where a branch is given off from a tube at an angle to the plane of the section. If this view be accepted, there appears to be no sufficient reason why *Mitcheldeania* should not be ranged with *Solenopora* and other similar forms, and included among the Calcareous Algæ—a position which its mode of occurrence and general structure has led me, for some time, to assign to this organism.

In addition to the three chief forms described above from British rocks, a

[12] *Op. cit.* ([8]).
[13] *Geol. Mag.*, Dec. III., Vol. III., p. 535, 1886.
[14] Vol. IX., p. 77, pl. v., 1886.
[15] *Op. cit.* ([4]), p. 16.

study of numerous thin sections from the Lower Carboniferous rocks of the north-west of England has revealed the presence of several distinct organisms, which will, I think, eventually be found to be referable to the Calcareous Algæ.

This meagre list appears to exhaust the genera known at the present time from the Lower Carboniferous rocks of Britain; and the only lime secreting plant so far recorded from the Mesozoic and Tertiary rocks of this country (if we except Rothpletz's sub-genus *Solenoporella*) is *Chara* from the Wealden beds of Sussex, the uppermost Jurassic of the Isle of Wight and Swanage, and the Oligocene of the Isle of Wight.

Outside of this country the literature on fossil Calcareous Algæ is much more extensive. The interest originally aroused on the Continent by the writings of Phillipi, of Unger of Vienna, Cohn, Rosanoff, Gümbel, Saporta, and Munier-Chalmas has been further maintained in our own time by Bornemann, Steinmann, Früh, Solms-Laubach,[16] Rothpletz, Walther, Kiaer, and others; while the more favourable conditions which obtained for the growth of these organisms, especially during Silurian, Triassic, and Tertiary times, has afforded a much wider field for their observation.

Thus, in addition to the forms recorded from this country, an important part has been played by members of the family of the *Dasycladaceæ*, together with such genera as *Spherocodium*, *Lithothamnion*, and *Lithophyllum*.

It is now time to consider the part played by these organisms in the formation of the sedimentary rocks through the successive geological periods.

ARCHÆAN.

In the Archæan rocks no undoubted remains of algæ have yet, so far as I am aware, been recorded, but Sederholm considers that certain small nodules in the Archæan schists of Finland may represent vegetable remains. I may also perhaps here refer to some curious oolitic structures which I met with in Spitsbergen in 1896 when examining the rocks of Hornsund Bay. These oolites occur on the south side of the Bay, and are closely connected with massive siliceous rocks which may represent old quartzites. The whole series is much altered, and detailed structure cannot now be made out. The rocks occur apparently stratigraphically below the massif of the Hornsund Tinde, and may belong either to the Archæan or the base of the Heckla Hook series. As, however, similar rocks have not been recorded from the type district of Heckla Hook, they may be referred provisionally to the Algonkian, and may represent the quartzites and earthy limestone of the Jotnian series of Scandinavia. They are mentioned here in connection with Mr. Wethered's view that oolites are essentially associated with the growth of *Girvanella*.

CAMBRIAN.

Passing on to the Palæozoic rocks, we find in the Cambrian deposits very few indications that Calcareous Algæ played any considerable part in their formation.

This is no doubt due, to some extent, to the conditions under which these deposits accumulated in the classical localities where true calcareous deposits are typically absent. In the Durness limestone, however, where considerable masses of dolomites occur, the conditions would appear at first sight to have been more suitable for the growth of these organisms; but even here the slow rate of accumulation and the large amount of contemporaneous solution may have militated against their preservation. At the same time, it is possible that a systematic search in the calcareous facies of the Cambrian rocks in the north of Europe and America may result in the discovery of the remains of some members of this group. That there is ground for this suggestion is shown by recent work in the Antarctic Continent.

Professor Edgworth David and Mr. Priestly have discovered among the rocks on the north-west side of the Beardmore Glacier dark grey and pinkish grey limestone containing the remains of Archæocyathinæ, Trilobites, and sponge spicules, together with abundant remains of a small Calcareous

[16] *Fossil Botany*. Oxford. 1891.

Alga referred provisionally to *Solenopora*. From the photographs exhibited by Professor David on the occasion of his address to the Geological Society I have little doubt that this reference is correct.

A further occurrence of *Solenopora* is also reported from fragments of a limestone breccia collected by the Southern party from the western lateral moraine of the same glacier. Speaking of the fauna discovered in this limestone, Prof. David remarks: 'The whole assemblage is so closely analogous with that found in the Lower Cambrian of South Australia as to leave no doubt as to the geological age of the limestones from which these fragments are derived.[17] This discovery, therefore, extends the vertical range of this widely distributed genus down to the oldest Palæozoic rocks. It is interesting to note that the rocks in which the *Solenopora* occurs on the Antarctic Continent contain a development of pisolite and oolite, and that this is also the case in the Australian equivalents. In 1887 and again in 1891 Bornemann described and figured species of *Siphonema* and *Confervites*[18] from the *Archæocyathus* limestones of Sardinia. As regards the former genus, it was shown by Dr. Hinde[19] to be congeneric with *Girvanella* (Nich and Eth). It is of interest, however, to note that Bornemann describes this form as a Calcareous Alga, and compares it with existing sub-aerial algæ growing on the surface of limestone rocks in Switzerland. The latter is stated by Seward to be possibly 'a Cambrian alga, but the figures and descriptions do not afford by any means convincing evidence.'

More recently, in 1904, Dr. T. Lorenz[20] has described remains of *Siphoneæ* from the Cambrian rocks of Tschang-duang in Northern China, for which he erects two new genera, *Ascosoma* and *Mitscherlichia*, placing them in a new family, the *Ascosomaceæ*. These algæ build important beds of limestone, the individuals often attaining a length of 4 cm. and a thickness of 1·5 cm. In 1907 Bailey reported *Girvanella* associated with oolites in the lowest Cambrian Man-t'o beds in China. It is probable, therefore, that as our knowledge of these rocks is extended, Calcareous Algæ will be found to play an important part in the Cambrian limestones of the Asiatic Continent and Australia.[21]

ORDOVICIAN.

In the Ordovician rocks, the remains of Calcareous Algæ are much more abundant; they are very widely distributed and for the first time they become important rock-builders. In Britain, the chief genera met with are *Girvanella* and *Solenopora*. These two organisms occur abundantly in the Scottish Ordovician rocks of the Girvan area, where they appear to have contributed largely to the limestones of the Barr Series in Llandeilo-Caradoc times.

As already mentioned, the genotype of *Girvanella*—*G. problematica*—was originally described by the late Professor Nicholson and Mr. Etheridge, jun., from the Craighead limestone, where it occurs in great numbers at Tramitchell. The officers of the Geological Survey also report it from the Stinchar limestone of Benan Hill.[22]

It occurs in the form of small rounded or irregular nodules, varying in diameter from less than a millimetre to more than a centimetre—many of the nodules showing marked concentric structure. During a recent visit to Girvan I was much struck by the important part played by this organism in the formation of these upper 'compact' limestones. In Benan Burn, where these beds are admirably exposed, the *Girvanella* nodules appear conspicuously on the weathered surfaces, being so abundant as to constitute thick layers of limestone.

Solenopora compacta var. *Peachii*, which, likewise, forms important masses of limestone, is found, like *Girvanella problematica*, most abundantly in the Girvan area, but at a somewhat lower horizon, namely, in the 'nodular limestone' and shales forming the lower sub-division of the Stinchar Limestone. It was

17 *Eleventh International Geol. Congress Report*, 1910, p. 775.
18 *Nova Acta Cæs. Leop. Car.* 1887 and 1891.
19 Hinde, *Geol. Mag.*, 1887, Dec. III., vol. IV., p. 226.
20 *Centralb. Min.*, 1904, p. 193.
21 Chapman, *Proc. Roy. Soc. Vict.*, 1911, p. 308.
22 *Mem. Geol. Surv. United Kingdom.* The Silurian Rocks of Britain vol. I., Scotland, pp. 487, 494, 496, 500.

originally described by Nicholson and Etheridge, jun., under the name *Tetradium Peachii,* from pebbles of the Old Red Conglomerate of Habbie's Howe, and was afterwards discovered to occur plentifully in the Ordovician limestone at Tramitchell and Craighead. It was subsequently found by Nicholson to be synonymous with the form *Solenopora* (*Stromatopora*) *compacta* (Bill). At Craighead it occurs in the shales as spheroidal and botryoidal nodules up to 4 cm. in diameter, while in the limestone itself the nodules may have a diameter of 7·5 cm. On freshly fractured surfaces it appears as buff-coloured on brownish spots, having a compact porcellaneous texture, while weathered surfaces often show a concentric structure. Under the microscope the tubes of this species vary in diameter from 50-80 μ.

In the Geological Survey Memoir it is recorded, under the original name of *Tetradium Peachii,* from the Stinchar Limestone of Benan Burn, Millenderdale, and Bougang, where it is accompanied by two other species, *S. filiformis* and *S. fusiformis,*[23] which contribute conspicuously to the deposit, often forming large masses of limestone. The horizon of the Stinchar Limestone is correlated by Professor Lapworth with the Craighead Limestone, and considered to represent the summit of the Llandeilo or the base of the Caradoc rocks of the Shropshire district. It is of interest to note that *Solenopora* is here accompanied at times by well-marked oolitic structure, and that the same is true of the pebbles with which it is associated in the conglomerate at Habbie's Howe.

Although the marked development of *Solenopora* found in the Stinchar Limestone ceases with the advent of the Benan conglomerate, the genus appears to have survived in the Girvan district into Upper Caradoc times, for Dr. Brown describes a new species (*S. lithothamnioides*) from Nicholson's collection from the Ordovician (? Silurian) beds at Shalloch Mill, where it is said to occur in conical masses the size of a walnut. The only beds in which we might expect algæ to occur in this locality are the nodular limestones or Dionide beds of the Whitehouse Group of Professor Lapworth's classification, but there is no mention of *Tetradium* or *Solenopora* from this locality in the fossil lists cited from Mrs. Gray's collection in the Survey Memoir.

As this point is of some interest, I have consulted Mrs. Gray, who very kindly sent me some small nodules which she had collected from the Whitehouse beds of Shalloch Mill. On slicing one of these I find that it is undoubtedly a *Solenopora,* and probably the species figured by Dr. Brown as *S. lithothamnioides.* A tangential section cut from this specimen shows clearly how the original specimen of *Solenopora* from Craighead was originally confused with *Tetradium* by Nicholson and Etheridge, jun.

South of the Scottish Border there is, so far as I am aware, only one locality from which Calcareous Algæ have been recorded in rocks of Ordovician age, namely, Hoar Edge in Shropshire. Here large examples of *Solenopora compacta* were obtained in 1888 by Professor Lapworth from the calcareous layers near the base of the Hoar Edge Sandstone. The specimens were handed to Professor Nicholson, who records the circumstance in his description of *S. compacta* in 1888.[24] The form occurs here at the base of the Caradoc beds, and therefore at an horizon which corresponds closely to that of the Craighead Limestone of Girvan.

Professor Lapworth also informs me that he has obtained specimens of *Solenopora* from a limestone in south-west Radnorshire. As the upper portion of the limestone in which it is found contains a Silurian fauna, it is possible that it is here present at a higher horizon, though the constancy with which it occurs elsewhere, in beds of Llandeilo-Caradoc age, would seem to point to the possibility that beds of Upper Ordovician age are also present in this area. In any case, its occurrence here is of considerable interest.

Foreign Ordovician.

Outside of Britain, the most important development of Calcareous Algæ in rocks of Ordovician age occurs in the Baltic Provinces.

As already stated *Solenopora* was first recorded from Herrküll in Esthonia, by Dybowski under the name of *Solenopora spongioides.* It occurs here in

[23] Brown, *op. cit.* (6), pp. 195–197. [24] *Op. cit.* (4), p. 22.

the Upper Caradoc or Borckholm beds of Schmidt's classification—where it makes up thick beds of limestone—and it is noteworthy that this horizon is practically identical with that at which *S. lithothamnioides* (Brown) occurs at Shalloch Mill.

Other specimens of *Solenopora* were collected by Professor Nicholson in Saak, south of Reval, from the underlying Jewe beds, an horizon which must correspond very closely to that of the Craighead Limestone of Girvan. Speaking of these beds, Nicholson and Etheridge remark: 'At this locality *S. compacta* not only occurs as detached specimens of all sizes, but it also makes up almost entire beds of limestone, indeed, some of the bands of limestone at Saak look like amygdaloïdal lavas, while others have a cellular appearance from the dissolution out of them of the little pea-like skeletons of this fossil.'[25]

In Professor Nicholson's collection from these beds Dr. Brown[26] afterwards distinguished two new species—namely, *S. nigra* and *S. dendriformis.* Thus in the Ordovician rocks of Esthonia, *Solenopora* plays quite as important a part (as a rock-forming organism) as it does in the Girvan district in Ayrshire.

In Norway again, in the Mjösen district to the north of Christiania, *Solenopora* occurs plentifully in Stage 5 of Kiaer's[27] Ordovician series. Here it is very abundant and often builds entire beds, while, further east, at Furnberg, Kiaer again records the occurrence of abundant nodules of *Solenopora compacta,* var. *Peachii.*

In addition to *Solenopora,* however, examples of another important group of Calcareous Algæ, the Siphoneæ, occur in great abundance in the Ordovician rocks of the Baltic region, where they play a part in the formation of calcareous rocks, scarcely less important than that played by *Gyroporella* and *Diplopora* in the rocks of the Alpine Trias.

The chief forms belong to the family of the Dasycladaceæ, which is represented in our present seas by the recent genus *Neomeris*; they include the genera *Palæoporella, Dasyporella, Rhabdoporella, Vermiporella, Cyclocrinus,* and *Apidium.* These algal limestones represent the horizons from the Jewe Limestone to the Borckholm beds inclusive. They were originally investigated by Dr. E. Stolley,[28] who described their occurrence in the numerous boulders which are strewn over the North German plain in Schleswig-Holstein, Pomerania, Mecklenburg, and Mark-Brandenberg. Many of these boulders can be identified by their lithological character and fossil contents as belonging to the Jewe beds of the Baltic Ordovician formations. Others have been derived from the overlying Wesenberg limestones, while yet others occur which resemble the Lyckholm beds of the Baltic succession. This assemblage proves that the boulders did not originate on the Swedish continent, but from the more easterly-lying districts, probably from a part of the Baltic between Oeland and Estland, now covered by the sea. Similar boulders are also known at Lund in Schœnen, on Bornholm, and near Wisby in the North of Gotland.

These facts appear to show that during the deposition of the Jewe and the overlying Wesenberg and Lyckholm limestones an algal facies obtained which extended from Oeland to Estland and as far north as the Gulf of Bothnia.

But even this area does not represent the full extent of this algal limestone facies in the North of Europe in Upper Ordovician times. In Norway, Kiaer[29] has shown by his detailed work in the Upper Ordovician rocks, Stage 5 of the Christiania district, the important part played by the *Dasycladaceæ* in this area. Here the Gastropod limestone in places forms a 'phytozoan limestone,' made up of *Rhabdoporella, Vermiporella,* and *Apidium* associated with a considerable development of oolite.

Again at Kuven and Valle, in the Bergen district, Reusch[30] and Kolderup[31] have described knolls of crystalline limestone containing abundant remains of

25 *Op. cit.* (8), p. 534. 26 *Op. cit.* (6).

27 *Faunistische Uebersicht d. Et.* 5. *Vid.-Selsk. Skr.* 1877, No. 3.

28 *Schr. d. naturw. Ver. f. Schleswig Holstein* Bd. XI. 1897, and references there given.

29 *Etage 5 i. Asker. Norges Geol. Undersogeles Aarbog,* 1902, No. 1.

30 *Silurfossiler og pressede Konglomerater* 1882 and *Bommeløen og Karmøen. Med. omgivelser* 1888.

31 *Et orienterende niveau Bergensskiferne. Rhabdoporellenkalk von Kuven und Valle. Bergens Museums Aarbog,* 1897.

Rhabdoporella (formerly described as *Syringophyllum*) associated with a gastropod and coral fauna. This horizon, they have unhesitatingly referred to zone 5a of Kiaer's Christiania sequence and state that it may be found stretching from Geitero in the S.S.W. by Kuven, Valle, and Trengereid to Skarfen on Osterø while Reusch has traced it further south to Stordø, near Dyviken and Vikenes. We have, therefore, in Upper Ordovician times, in the north of Europe, one of the most remarkable developments of algal limestones met with throughout the geological succession.

In North America Calcareous Algæ are represented in Ordovician times by *Solenopora compacta,* which occurs in the Trenton and Black River limestone groups, whence it was originally described by Billings under the name of *Stromatapora compacta.* It therefore occurs in America at about the same horizon as in Saak and Britain.

We may also note the occurrence of *Girvanella* in the underlying Chazy limestone. It was originally described by the late Professor H. M. Seeley[32] under the name of *Strephochetus ocellatus,* but is now generally admitted to be a species of *Girvanella.*[33]

Other forms referred to this genus have also been reported by Schuchert from rocks of undoubted Ordovician age on the east coast of the Behring Straits.[34]

SILURIAN.

In Britain the only horizon of Silurian age at which Calcareous Algæ play an important part is the Wenlock Limestone. Mr. Wethered some years ago from the beds of this age described the occurrence of *Girvanella* tubes at May Hill, Purley, near Malvern, and Ledbury.[35] Of these beds Mr. Wethered remarks: 'The most interesting result of the microscopic study of these rocks was the discovery of new and interesting forms of *Girvanella* and the fact that this organism has taken so important a part in building up the limestone.' It may here be mentioned that it was whilst studying these forms in the Wenlock Limestone that Mr. Wethered first began to favour the suggestion of Rothpletz, published two years previously, that *Girvanella* might belong to the Calcareous Algæ, for he remarks: 'I certainly think that the forms which I have discovered in the Wenlock Limestone seem more favourable to the vegetable theory of the origin of this fossil than those described in my former paper, and possibly it may be allied to the Calcareous Algæ.'

So far as I can ascertain, this is all that has been published up to the present time with regard to the occurrence of Calcareous Algæ in British Silurian rocks; but I have every confidence that a more thorough microscopic examination of these rocks will reveal the presence of other examples of this interesting group of organisms.

Foreign Silurian.

Outside of Britain we find at this period, however, a marked algal development, and this again occurs in the Baltic area, where, especially in the island of Gotland, algal growths contribute largely to several of the limestones and marls. It is an interesting fact that very shortly after the disappearance of the various members of the *Dasycladaceæ* which were so much in evidence in Ordovician times, we should have the remarkable development of another group of the Siphoneæ, which, quickly reaching a maximum, built up in their turn abundant calcareous deposits. Nodules from these limestones have long been known from Gotland under the name of 'Girvanella Rock,' and have been recorded by Stolley[36] in boulders scattered over the North German plain. In 1908, however, Professor Rothpletz showed, in his interesting work on these Gotland deposits,[37] that the forms hitherto alluded to under the term 'Girvanella' were in reality referable to two different genera. One of these he showed to be a new species of *Solenopora,* to which he gave the name *S. got-*

[32] *Am. Journ. Sci.*, vol. XXX., 1885, p. 355.
[33] *Op. cit.* (19)
[34] See Haug. vol. II., pt. 1, p. 643.
[35] *Q.J.G.S.*, vol. xlix., p. 236, 1893.
[36] *Op. cit.* (28).
[37] *Op. cit.* (8).

landica (distinguished from *S. compacta* by the comparatively small dimensions of the tubes, which are only about one quarter of the diameter of the latter species); the other he referred to his genus *Sphærocodium,* which he had created in 1890 for certain forms from the Alpine Trias.[38] The presence here of *Solenopora* in beds of undoubted Silurian age is an interesting fact and would lead us to expect that it may also some day be met with in rocks of a corresponding age in Britain.

Of the different forms of algæ which occur in these Gotlandian deposits, perhaps the most interesting is *Sphærocodium,* which occurs at several horizons in the succession. It first makes its appearance in the marl immediately overlying the Dayia flags—approximately of Lower Ludlow age—where it occurs in considerable masses. Through the kindness of Dr. Munthe,[39] who has made a special study of these beds in southern Gotland, I have been able to examine specimens of this interesting genus. In external appearance they resemble very closely nodules of *Ortonella* from the Lower Carboniferous rocks of the N.W. of England; some of the nodules appear to have reached a diameter of 4 cms. The marl is overlain by sandstone and oolite, which are succeeded by an argillaceous limestone rich in nodules of *Sphærocodium gotlandicum* and well exposed at Grotlingbo, where it is closely associated with oolite. Among the fossils of this limestone *Sphærocodium* itself plays the most important rôle.

In the overlying 'Iliona Limestone,' *Sphærocodium* is decidedly rare and its place is taken by *Spongiostroma.* It is, however, found not infrequently forming a thin crust on the surface of the nodules of *Spongiostroma.* In appearance, *Spongiostroma* resembles very closely the nodules of *Sphærocodium,* showing the same concentric arrangement round coral fragments and a total absence of the radial structure which is so characteristic of *Solenopora.*

The actual systematic position of this organism, if organism it be, is still undecided. In his original description of this genus from the Carboniferous rocks of Belgium, Gurich[40] refers it provisionally to the Protozoa, while Rothpletz,[41] who has described two species *S. balticum* and *S. Holmi* from the Gotlandian of Gotland, although admitting the difficulties of assigning it to any group of the animal kingdom, decides in favour of its hydrozoan affinities.

As will be pointed out later, there appears to be no good reason why *Spongiostroma* may not be indirectly due to the presence of algal growths; but whatever may be the final position assigned to it, there can be no doubt as to its importance as a rock-building form in the Iliona limestone of Gotland. The wide extent of this algal horizon in the Upper Silurian of the Baltic area is shown by the abundance of boulders of these rocks scattered over Schleswig-Holstein, and it is probable that a careful examination will show the presence of this facies in the Silurian of the eastern Baltic Provinces.

We may conclude, therefore, that the development of the *Sphærocodium* beds of Gotland probably originally occupied nearly as wide an extension in the Baltic area as did the *Rhabdoporella* Limestones during the Ordovician Period.

With regard to other occurrences of Calcareous Algæ in Silurian rocks, it will be sufficient to note that of *Girvanella* in the Silurian limestones of Queensland, recorded by Mr. G. W. Card in 1900,[42] and more recently by Mr. Chapman from Victoria.[43]

Quite recently Mr. R. Etheridge, jun., of Sydney,[44] has described 'an organism allied to *Mitcheldeania* from the Upper Silurian rocks of New South Wales'; the figures given, however, and the description are not convincing that his identification can be accepted. The size of the tubes, which are from five to six times as large as those of *M. gregaria,* would alone appear to remove this organism from Mr. Wethered's genus and also possibly from the Calcareous Algæ.

[38] *Bot. Cent.*, vol. LII., p. 9, 1890.
[39] *Geol. Foren. Förhandl. Stockholm,* 1910, Bd. 32, H. 5, p. 1397.
[40] *Mem. du Musée Roy. d'Hist. Nat. de Belgique,* tome III., 1906.
[41] *Op. cit.* ([8]).
[42] *Bull. Geol. Surv. Queensland,* No. 12, pp. 25-32, pl. III. 1900.
[43] *Rep. Austr. Assn. Adv. Sci.*, 1907-1908.
[44] *Rec. Geol. Surv. N. S. Wales,* vol. 8, pt. 4, 1909, p. 308, pl. 47.

DEVONIAN.

So far as I am aware, there is only one recorded occurrence of Calcareous Algæ from the Devonian rocks of Britain—namely, the Hope's Nose limestone of Devonshire, from which Mr. Wethered [45] has described aggregations of tubules resembling *Girvanella*, but in a very poor state of preservation. It is hoped that this meagre record will be increased in the near future.

Foreign Devonian.

On the Continent the reported occurrences are, so far, equally poor. At the same time, the cursory examination which I was able to make of the thin sections of the Devonian limestones exhibited in the Brussels Museum leads me to expect that a careful investigation of the Belgian Devonian limestones will yield other examples besides *Spongiostroma.*

CARBONIFEROUS.

We now reach the period in Paleozoic times when Calcareous Algæ attained their maximum development in England, a development rivalling that which obtained in the Ordovician rocks of Scotland and the Gotlandian of the Baltic area. The genera represented include *Girvanella, Solenopora,* and *Mitcheldeania,* while in addition to these there occur several lime-secreting organisms which, though still undescribed, will, I think, ultimately come to be included among the Calcareous Algæ. The most interesting of these organisms I have recently figured from the Lower Carboniferous rocks of Westmorland, where it forms a definite zonal horizon or 'band.' [46] For this form, on account of its stratigraphical importance and for facility of reference, I propose the generic name of *Ortonella.*[47]

Again, at the same horizon in the North-West Province I have frequently noticed concretionary deposits of limestone which occur as finely laminated masses, the laminæ often lying parallel to the general direction of the bedding planes, which, on microscopic examination, show no definite or regular structure, but have every appearance of being of organic origin. Many of these puzzling forms resemble very closely the somewhat obscure structures found in the Visean limestones of the Namur basin in Belgium, of which beautiful thin sections are displayed in the Natural History Museum at Brussels,[48] and which Gürich has described and figured under various names—*Spongiostroma, Malacostroma,* &c., and which he has included under a new family, the *Spongiostromidæ,*[49] and a new order, the *Spongiostromaceæ.* He gives the following definition of the family: 'Organismes marins, incrustants, coloniaux, à structure stratifiée. La structure de la colonie est indiquée, à l'état fossile, par la disposition de petits grains opaques (granulations), entre lesquels il y a des interstices, tantôt plus étroits, tantôt plus larges—canaux du tissu et canaux coloniaux—donnant naissance à un tissu spongieux. Dans plusieurs formes, on a observé des Stercomes,' and suggests that they may possibly have been encrusting foraminifera.

I must confess that neither in the original sections nor in the beautiful illustrations which accompany his work, can I see any grounds for referring these structures to the Protozoa.

As regards the British specimens, I have long regarded them as due, directly or indirectly, to the work of Calcareous Algæ, partly on account of their intimate association with well-developed examples of these organisms, and also on account of the entire absence of foraminifera and other detrital organisms wherever this structure occurs. As, however, I have little doubt that they are closely connected in their mode of origin with the Belgian specimens, we may conveniently speak of them under the general term *Spongiostroma.*

Some of the best examples known to me occur associated with *Ortonella* in

[45] *Q.J.G.S.*, 1892, vol. XLVIII., p. 377, pl. ix., fig. 3.
[46] *Q.J.G.S.*, 1912, vol. LXVIII., pl. LXVII., fig. 2.
[47] From Orton, a village between Shap and Ravenstonedale, where this organism occurs in great abundance.
[48] One of these is also exhibited at the Jermyn Street Museum.
[49] *Op. cit.* ([40]).

the '*Productus globosus* band' near the summit of the '*Athyris glabristria* zone' in the Shap district. They occur here in considerable masses, often many inches in thickness, and form undulating layers parallel to the bedding, and somewhat resembling huge ripple-marks. Thin sections show little definite structure, but consist of what appears to be an irregular flocculent precipitate of carbonate of lime, the interstices being filled with secondary calcite. Some of the layers resemble almost exactly, both in hand specimens and microscopic structure, the figures of *Malacostroma concentricum* given by Gürich in plates XVII. and XX.[50] Others approach closely to the same author's figures of *Spongiostroma*, *Aphrostroma*, etc. In all cases they appear to be due to the precipitation of carbonate of lime in the neighbourhood of algal growths. I have also met with similar deposits, not only at other horizons in the Lower Carboniferous rocks of the North of England, but also in the Forest of Dean and in the rocks of the Avon Gorge; while quite recently Mr. C. H. Cunnington has sent me examples from several horizons in the Carboniferous Limestones of South Wales.

Girvanella.

This organism appears to play a considerable part in the formation of calcareous deposits in the Lower Carboniferous rocks of Britain. Its presence in these rocks was first suggested by the late Professor Nicholson,[51] in his paper where he remarks: 'I have found some of the Carboniferous Limestone of the North of England to contain largely an ill-preserved organism which will, I think, prove to be referable to *Girvanella*.' This prophecy has turned out to be fully justified not only as regards the North of England, but also in the case of the Lower Carboniferous beds of other districts. In 1890 Mr. E. Wethered described[52] two new forms of this genus from the Lower Carboniferous rocks of the Avon Gorge and Tortworth, viz.: *G. incrustans*, with tubes having a diameter of 0 1 mm., and *G. Ducii* with a diameter of ·02 mm. Mr. Wethered appears to rely chiefly on the size of the tubes for the differentiation of these species, but as this distinction was made at the time when *Girvanella* was still considered to belong to the Rhizopods, and as the size of the tubes frequently varies in the same specimen, it is doubtful whether these species can be maintained. Mr. Wethered's specimens were obtained from the limestone near where the Bridge Valley Road joins the river bank, apparently at the base of Dr. Vaughan's Upper Dibunophyllum Zone. The position of this limestone is of interest, as it appears to correspond very closely with the horizon of the '*Girvanella* Nodular Bed,' which forms a well-marked band at the base of the Upper Dibunophyllum Zone throughout the whole of the North and North-West of England. Indeed, I have traced this band at intervals from the neighbourhood of Ford, near the Scottish Border, southwards through Northumberland and the Pennine area to Penygent, and from the west coast at Humphrey Head through Arnside and Shap to the east coast, near Dunstanburgh. These organisms must, therefore, have flourished over an area of at least 3,000 square miles in the North of England alone.

The *Girvanella* tubes found associated with these nodules usually occur in two distinct sizes having diameters of ·03 and ·01 mm. respectively. The two forms are closely associated, but the finer tubes occur in greater abundance, and are much more closely interlaced. They resemble Mr. Wethered's description of the two species from Gloucestershire, and the figures he gives in illustration of these might serve very well to represent our northern forms.

The best exposure showing the important development of these *Girvanella* nodules is to be found on the dip slopes forming the eastern shore of Humphrey Head in Morecambe Bay, where the base of the Upper Dibunophyllum zone is exposed over a considerable area.

Solenopora.

The discovery of this genus in the Lower Carboniferous rocks of Westmorland is of considerable interest, as its occurrence here gives us some insight into

[50] *Op. cit.* ([40]). [51] *Op. cit.* ([4]), p. 24.
[52] *Q.J.G.S.*, 1890, vol. 46, p. 280, pl. XI., figs. 1 and 2.

the history of its wanderings between the time when we last recorded it in the Gotlandian rocks of the Baltic Area, and its subsequent reappearance in the Lower Oolite of Gloucestershire. Whether it lived in the Baltic area during the Devonian and Carboniferous periods is, however, still unknown. The fact of its occurrence in the Caradoc, Carboniferous and Jurassic rocks of the British Isles would appear to point to its existence not far off during the intervening periods, and I have hopes that before long it may be found in the Silurian, and possibly also in the Devonian rocks of this country.

In Westmorland and Lancashire *Solenopora* occurs in considerable abundance near the local base of the Lower Carboniferous rocks, and contributes largely to the formation of limestone deposits. It is present wherever the lowest beds of the succession are exposed, as at Shap, Ravenstonedale, and Meathop, and must formerly have flourished over a considerable area.

Though bearing a general resemblance, both in hand specimens and in microscopic structure to the Ordovician and Jurassic forms, it has recently been shown by Dr. G. J. Hinde to be specifically distinct.[53] It occurs as small, spheroidal nodules up to an inch in diameter, having a markedly lobulate outline embedded in compact and usually dolomitic limestones, and it is occasionally associated with oolitic structure. When fractured, it exhibits the compact porcellanous texture and pale brownish tint, characteristic of specimens of the genus found at other horizons, while weathered surfaces frequently show a concentric and occasionally a radially fibrous structure. It is noteworthy that the thallus of this organism shows no trace of dolomitisation, even when embedded in limestone containing over 30 per cent. of $MgCo_3$. The profusion of this form in Westmorland would lead one to expect its occurrence in other districts where the lowest Carboniferous zones are developed; but so far as I am aware, no such occurrence has yet been recorded. It may be of interest, therefore, to mention here that a few years ago my friend, Mr. P. de G. Benson, brought me a specimen of rock from near the base of the succession in the Avon Gorge, which on cutting I found to contain several examples of *Solenopora* identical with the Westmorland form. It is probable, therefore, that a careful microscopic examination of the lower horizons of the Carboniferous rocks of the S.W. Province will lead to the discovery of other examples of this interesting genus.

Mitcheldeania.

The specimens of *Mitcheldeania Nicholsoni* originally described by Mr. Wethered were obtained from Wadley's Quarry, near Drybrook, Mitcheldean, from the lower limestone shales near the base of the succession. Professor Sibly, who has recently made a careful study of the lower Carboniferous succession in the Forest of Dean,[54] has traced this algal layer over a considerable area, and considers it to represent a horizon near the top of K 2 of the Bristol sequence. He has also noted examples of *Mitcheldeania* at a higher level—namely, in the Whitehead limestone, an horizon corresponding probably to the base of O 2. During a recent visit to the Mitcheldean district I collected specimens from the lower shales, and also from the Whitehead Limestone, and, thanks to Professor Sibly's kind directions, I was able to see numerous sections in which he has found this algal development. There can be no doubt that *Mitcheldeania* is here an important rock-forming organism, at least at two horizons in this district, and that it occurs over a considerable area. In the case of the upper horizon it frequently contributes largely to the rock, forming in places almost entire layers in the Whitehead Limestone. With regard to the forms met with at these two horizons, the upper one, found in the Whitehead Limestone, agrees exactly in general characters and mode of occurrence, and also in its detailed microscopic structure, with Nicholson's species, *M. gregaria*, from Kershope Foot; the character of the two sets of tubes, their size and mode of arrangement is identical and it is impossible to distinguish between sections of well-preserved specimens from the two localities. Unfortunately, the specimens from the lower shales at Mitcheldean are very badly preserved, but if Nicholson's distinction between the two species holds,

[53] *Geol. Mag.* 1913, Dec. V., vol. X., p. 289, pl. X.
[54] *Geol. Mag.*, 1912, Dec. V., vol. IX., p. 417.

we shall have to speak of the form from the lower horizon at Mitcheldean as *M. Nicholsoni*, and that from the Whitehead Limestone as *M. gregaria.* Frequently associated with the latter is a curious *festoon-like* growth, while in the lower horizon a *Spongiostroma*-like structure is often found in the matrix of the rock between the larger tubes of *M. Nicholsoni.* Some years ago Mr. Wethered [55] also recorded a similar form of *Mitcheldeania* from the base of the middle limestones of the Avon Gorge, while I have myself collected nodules containing specimens apparently referable to *M. Nicholsoni* from the Modiola Shales near the base of the Bristol succession. Interesting as the development of *Mitcheldeania* in the Forest of Dean undoubtedly is, its real home in Britain is in north Cumberland and the Scottish Border, where it flourished to a remarkable extent in the shallow water lagoons which spread over so large an area in the north of England during early Carboniferous times Over the greater part of north Cumberland and the east of Roxburgh we find a remarkable development of algal limestones in the formation of which *Mitcheldeania* plays a very important part. It is met with especially at two horizons, an upper one, lying immediately below the Fell Sandstone, and a lower one in the middle of the underlying series of limestone and shales. The lower horizon is especially interesting on account of the thick masses of limestone composed almost entirely of algal remains. Though *Mitcheldeania* forms the basis of this reef-like development, it is accompanied by other algal forms, especially bundles of the minute tubules of *Girvanella*, together with coarser tubes reminding one of the *Spherocodium* deposits of Gotland. In places again the marked concentric coatings resemble certain forms of *Spongiostroma.* The substance of the reef has frequently formed round the remains of Orthoceratites—indeed, the chief layer is usually associated with remains of these Cephalopoda. With other layers occur tubes of Serpulæ and remains of Ostracoda. In addition to the limestone of this massive reef, abundant nodules of *Mitcheldeania* lie scattered through the calcareous shales both above and below.

The upper layer, from which Nicholson obtained his type specimen of *M. gregaria* at Kershope Foot, forms a compact limestone several inches thick. It is made up of small spheroidal nodules about half-an-inch in diameter, and occurs a short distance below the Fell Sandstone. It can be traced over the whole of north Cumberland and north-west Northumberland from near Rothbury on the east to the Scottish Border at Kershope Foot, and from the head waters of the Rede in the north to the Shopford district in the south. This layer must therefore have been originally deposited over an area of at least 1,000 square miles. The horizon of the upper band is almost certainly that of the C. zone of the Bristol sequence.[56], [57] It is quite possible, therefore, that it is contemporaneous with the Whitehead limestone of Mitcheldean. This supposition receives support from two other pieces of evidence. In the beds underlying the *Mitcheldeania gregaria* band in north Cumberland occur calcareous nodules largely made up of tubes of *Serpulæ*—an organism which is completely absent from the Westmorland succession, but which is reported by Prof. Sibly from the lower limestone shales containing *Mitcheldeania* in the Forest of Dean district. Again, this upper algal layer in Northumberland and Cumberland is almost immediately overlain by the Fell Sandstone series, while the Whitehead limestone at Mitcheldean passes immediately upwards into a sandstone, the Drybrook Sandstone of Prof. Sibly, which was originally correlated with the Millstone Grit, but was shown by Dr. Vaughan in 1905 to belong to the Lower Carboniferous series. It would be interesting if further researches should prove the existence of a former gulf at the end of Tournaisian times, running from the Forest of Dean to the east of North Wales, through North Cumberland to the southern slopes of the Cheviot Isle, with a branch given off eastward into Westmorland.

In any case, it is a remarkable fact that we have a great development of algal deposits at this period in Gloucestershire, Westmorland, Lancashire, north Cumberland, and Northumberland.

[55] *Brit. Assn. Rep.*, 1898, p. 862.
[56] *Geology in the Field*, 1910, pt. 4, p. 683.
[57] *Q.J.G.S.*, vol. LXVIII., 1912, p. 547.

Ortonella.

This form, as already mentioned, occurs in great abundance in the algal band in the '*Athyris glabristria* zone' of the North-West Province. It is found in spherical nodules up to the size of a small orange. In miscroscopic sections it resembles *Mitcheldeania* in so far as it consists of a series of tubes growing out radially from a centre. It differs, however, from this genus in many important respects. All the tubes are approximately of the same size, and there is no evidence of alternating coarse and fine tufts arranged concentrically, as in the case of *Mitcheldeania.* Further, the tubes are not undulating as in that genus, and therefore in thin slices lie for a long distance in the plane of the section. They are much more widely spaced and show marked dichotomous branching, the bifurcations making a nearly constant angle of about 40°, and there is a strong tendency for the branching to take place in several tubes at about the same distance from the centre of growth, producing a general concentric effect in the nodule.

The diameter of the tubes is decidedly less than those in Mitcheldeania, being usually little more than half the size of the larger tubes of *M. gregaria.* The nodules of this genus occur in great profusion, contributing largely to the formation of the shaley dolomite at the base of the '*P. globosus* band' throughout the Shap, Ravenstondale, and Arnside districts in Westmorland and Lancashire.

In addition to these genera there occur also two other encrusting calcareous growths which require mention. The first of these appears in thin sections in the form of a 'festoon-like' growth, surrounding fragments of Calcareous Algæ, especially *Mitcheldeania* and *Ortonella.* I have met with it abundantly in the 'Algal band' in the North-West of England, but it also occurs not infrequently associated with *Mitcheldeania* in the Whitehead Limestone in the Forest of Dean, while a similar structure occurs associated with *Mitcheldeania gregaria* in north Cumberland.

Although the exact nature of this growth is still undecided, I mention it here on account of its invariable association with undoubted Calcareous Algæ.

The other deposit is the form already alluded to under the term *Sphærocodium,* which I have found forming considerable masses of rock in many districts where the Lower Carboniferous beds are exposed; not only in Westmorland and North Cumberland, but also in the Bristol district, the Forest of Dean, and South Wales.

Foreign Carboniferous.

From its general similarity to the British deposits we might expect to find examples of an algal development in some portion of the Belgian Lower Carboniferous succession. As already mentioned, large masses of encrusting calcareous deposits have been described by Gurich [58] from the Visean limestones of the Namur basin as *Spongiostroma*, &c., which, though referred by him to the *Rhizopoda,* may very well be calcareous precipitates deposited by algal influence. Many of these deposits are similar to those mentioned above from British rocks.

No undoubted remains of Calcareous Algæ have, however, yet been recorded from these Belgian rocks. It may be of interest, therefore, to mention the recent discovery by Professor Kaisin, of Louvain, of undoubted algal remains in the beds overlying the Psammites-de-Condroz at Feluy on the Samme. The form found here resembles *Ortonella* of the Westmorland rocks, but the tubes are much finer, and it may turn out to represent a species of *Micheldeania.* During a recent visit to Belgium I had the pleasure of visiting the Comblain au Pont beds, in the Feluy section, with Professor Kaisin, and, although these beds have been previously classed as Devonian, I agree with him that they probably belong to the base of the Carboniferous and correspond approximately to K of the Bristol sequence. In the company of Professor Dorlodot and Dr. Salée, I also visited the chief sections of the Visean, and we succeeded in discovering at least three horizons at which nodular concretionary structures, probably referable to algal growths, occurred. It is pretty certain, therefore, that careful microscopic investigation of the Belgian rocks will show the presence of Calcareous Algæ at more than one horizon.

Again Schubert [59] has recently described two new rock-forming genera—

[58] *Op. cit.* ([40]) [59] *Jahrb. d. k.-k. geol. Reichsanstalt,* 1908, p. 382.

Mizzia and *Stolleyella*—from a dolomite in the Upper Carboniferous of northern Dalmatia, while a species of *Girvanella* (*G. sinensis*) has been described by Yabo[60] from the (?) Carboniferous rocks of San-yu-tung and other localities in China.

PERMIAN AND TRIAS.

In Britain I have met with no reference to the occurrence of Calcareous Algæ in rocks of this period, but quite recently Mr. Cunnington, of H.M. Geological Survey, sent me a few nodules from the base of the 'Permian' near Maxstoke; in thin sections they resemble very closely fragments of *Spongiostroma* from the Carboniferous Limestone, and may be derived from that formation.

Abroad, masses of limestone, composed almost entirely of remains of *Diplopora* and *Gyroporella*, have long been known from the Muschelkalk and lower Keuper beds of the Eastern Alps, notably the Mendola Dolomite, the Wetten limestone of Bavaria, and the Tyrolian Alps—from the Zugspitz to Berchtesgaden, also from the Hauptdolomit and the Fassa Dolomite of the North limestone Alps and the stratified Schlern dolomite of the Southern Tyrol. In the Lombard Alps the same facies reappears, and *Diplopora annulata* occurs abundantly in the well-known Esino limestone above Varenna.

In 1891 Rothpletz[61] showed that certain spherical bodies in the Triassic beds of St. Cassian, formerly regarded as oolitic structures, were in reality algal growths, and referred them to a new genus, *Sphærocodium*, on account of their apparent resemblance to the living form *Codium*. He describes them as encrusting organisms forming nodules up to several centimetres in diameter. They contribute substantially to the rocks in which they occur, and are found especially in the Raiblkalk, the Kossenerkalk, and the Plattenkalk.

JURASSIC.

The Mesozoic rocks of Britain contain but few examples of marine algal limestones, and important occurrences are confined to the Jurassic Rocks. The forms met with are limited to two genera, *Girvanella* and *Solenopora*.

Tubes of *Girvanella* occur fairly abundantly in the British Oolites, especially in the well-known Leckhampton Pisolites, and Mr. Wethered, who has made a special study of oolitic structures, appears inclined to refer all oolitic structures to organic agency of this nature.

The examples of *Solenopora* met with in the Great Oolite[62] and Coral Rag are of special interest. In both cases they attain very much larger dimensions than any species yet discovered in the Palæozoic rocks.

At Chedworth, near Cirencester, I have collected masses of *Solenopora jurassica*, measuring up to a foot across, in which the original pink tint is still so conspicuous on freshly-fractured surfaces as to give rise to the local appellation of 'Beetroot Stone,' and the colour also reminds one of the red algæ growing in great profusion at the present day in the Gulf of Naples.

It is also recorded from the same horizon from near Malton in Yorkshire by Dr. Brown,[63] and also, on the authority of the late Mr. Fox Strangways, by Professor Rothpletz.[64]

In Yorkshire, however, one form undoubtedly occurs at a higher horizon—namely, in the Coral Rag of the Scarborough district, where it is well known to local collectors. Specimens which I have collected from this horizon at Yedmandale and Seamer also attain a considerable size—up to six inches in their longest dimension.

The name *Solenopora jurassica* was given by Professor Nicholson in manuscript to specimens from Chedworth, and was adopted by Dr. Brown in his description of the specimens from both Chedworth and Malton in Nicholson's collection.

Professor Rothpletz points out that specimens examined by him from

[60] H. Yabe, *Science Reports of the Tôhoku Imp. Univ.*, Japan, 1912.
[61] *Zeitsch. d. deut. Geol. Ges.*, 1891, vol. XLIII., pp. 295–322, pls. XV.–XVII., 1891.
[62] *Proc. Cot. Nat. Club.* 1890, vol. X., p. 89.
[63] *Op. cit.* ([6]), p. 150. [64] *Op. cit.* ([8]).

Yorkshire differ from the genotype in the fact that the cells are typically rounded in cross section and by the absence of perforations in the cell-walls, and he therefore proposes to separate it as a new genus *Solenoporella.* It seems probable that some confusion has arisen between the specimens to which Nicholson originally gave the name of *S. jurassica* from the Great Oolite of Chedworth and other specimens from Malton from a higher horizon [65]—the Coral Rag—examined by Dr. Brown and Professor Rothpletz.

The former author indeed figures a longitudinal section from Chedworth (Glos.) and a tangential section from Malton (Yorkshire), as the same species.

I have collected specimens from both horizons and consider that the Chedworth specimens, to which the name of *Solenopora jurassica* was originally given, represent a species of true *Solenopora*, showing closely packed cells with polygonal outline in tangential section, the form from the Coral Rag of Yorkshire, with distinct circular outline to the tubes in tangential section, is specifically, if not generically distinct, and is that described by Rothpletz as *Solenoporella.*

If this view be correct we should continue to speak of the specimens from the Great Oolite at Chedworth as *Solenopora jurassica,* while those from the Coral Rag of Yorkshire must be known as *Solenoporella sp.* Rothpletz.

Foreign Jurassic.

In foreign Jurassic rocks the recorded occurrences of Calcareous Algæ are surprisingly few.

Quite recently, however, Mr. H. Yabe [66] has described a new species of *Solenopora,* under the title *Metasolenopora Rothpletzi,* from the Torinosu limestone of Japan. This discovery is of interest, as it carries the known occurrence of *Solenopora* up to the base of the Cretaceous, in which formation *Lithothamnion* appears and thenceforward becomes the chief representative of the rock-building Coralline Algæ.

CRETACEOUS.

We here reach the period when *Lithothamnion* and its allies begin to make their appearance. They have not yet been recognised in British rocks, but are widely distributed in continental deposits. They occur in the Cenomanian of France, in the Sarthe and the Var, but especially in the Danian of Petersburg, near Maestricht.

Other forms which may be mentioned are *Diplopora* and *Triploporella.* The former is met with abundantly in the lower Schrattenkalk in certain districts, especially Wildkirchli, where it plays a considerable part in the formation of the deposit.[67]

TERTIARY.

In Britain no example of marine Calcareous Algæ have, so far as I am aware, yet been reported, but considerable deposits of freshwater limestone, rich in remains of the lime-secreting Thallophyte *Chara,* have for long been known from the Oligocene of the Isle of Wight.

Foreign Tertiary.

On the Continent, however, thick deposits rich in *Lithothamnion* and *Lithophyllum* have been known for many years. Of these, I may mention especially the well-known Leithakalk of the Vienna Basin and Moravia, which it will be remembered formed the subject of Unger's important monograph in 1858.[68]

CONCLUSIONS.

The facts given above regarding the geological distribution and mode of occurrence of these organisms lead us to several interesting conclusions. In the

[65] See Fox Strangways, *Geol. Mag.*, 1894, Dec. IV., vol. I., p. 236.
[66] *Op. cit.* (60), p. 2.
[67] Arbenz, *Vierteljahrschr. Naturf. Ges.-Zürich,* 1908, vol. LIII., pp. 387–392.
[68] *Denksch. k. Akad. Wiss. München,* 1858, vol. XIV., p. 13.

first place, there can be no doubt from the examples described above that they play a very striking part as rock-builders at many different horizons in the geological series. At the same time, it is evident that not only are certain forms restricted to definite geological periods, but that they had also a wide geographical range, and on this account these organisms will often be found valuable as zonal indices either alone or in conjunction with various other organisms. As an example of this wide distribution we may cite *Solenopora compacta,* which flourished so abundantly during Llandeilo-Caradoc times not only in the Baltic area and Scotland, but also in England, Wales, and Canada; again, the wonderfully persistent development of the *Rhabdoporella* facies over the whole of the Baltic area at the close of Ordovician times was of so marked a character that boulders of these rocks scattered over the North German plain can be made use of in tracing the direction of flow of the ice-sheet during glacial times.

To take examples nearer home, the '*Ortonella* band,' found throughout Westmorland and north Lancashire near the summit of the Tournaisian, occurs so constantly at the same horizon as to constitute one of the most valuable zonal indices in the succession in the North-West Province, and can be used with the greatest confidence not only for correlating widely separated exposures, but it has also afforded valuable evidence of tectonic disturbances. Other examples are supplied by the '*Girvanella* Nodular band' at the base of the Upper Dibunophyllum Zone, and the *Mitcheldeania gregaria* beds in the north of England and in the Forest of Dean.

Again the presence of these organisms at a particular horizon furnish us with interesting evidence as to the conditions which obtained during the accumulation of these deposits.

At the present day Calcareous Algæ flourish best in clear but shallow water in bays and sheltered lagoons. As a good example we may take the algal banks in the Bay of Naples, described by Prof. Walther,[69, 70] where *Lithothamnion* and *Lithophyllum* flourish to a depth of from 50-70 metres. There is seldom any muddy sediment on these banks, though detrital limestone fragments are widely distributed. Another interesting point is the constant association of fossil Calcareous Algæ with oolitic structure and also with dolomite.

Thus oolites occur in connection with *Solenopora* in the lower Cambrian of the Antarctic, in the Craighead Limestone at Tramitchell, in the Ordovician rocks of Christiania, in the Silurian of Gotland and in the Lower Carboniferous Limestone of Shap; while in the Jurassic rocks of Gloucestershire and Yorkshire it occurs in the heart of the most typical oolitic development to be met with in the whole geological succession. Though Mr. Wethered has made out a good case for the constant association of *Girvanella* tubes with oolitic grains there are many cases in which their association cannot be traced. M. Cayeux[71] in writing of a mass of *Girvanella* from the ferruginous oolites of the Silurian rocks of La Ferrière-aux-Etangs expresses his opinion that *Girvanella* encrusts the oolite grains but does not form them, and that it is really a perforating alga of a parasitic nature.

The presence of dolomites in connection with algal deposits at different geological horizons appears to have taken place under definite physiographical conditions similar to those which obtain to-day in the neighbourhood of coral reefs. Such lagoon conditions would come into existence *either* during a period of subsidence *or* during a period of elevation, and this is just what we find when we examine the periods at which these reefs are most persistent.

Thus the Girvan Ordovician reef occurred during an elevation which culminated with the deposition of the Benan Conglomerate; the Lower Carboniferous 'Algal band' in Westmorland was laid down during the subsidence which followed the Old Red Sandstone continental period; the Upper *Girvanella* Nodular band occurred when the Marine period of the Lower Carboniferous was drawing to a close and a general elevation was taking place. Similar conclusions could be drawn from other periods recorded above did time permit.

[69] *Zeitsch. d. deut. Geol. Ges.* 1885, p. 229.

[70] *Abh. d. Königl. Preuss. Akad. der Wiss.* 1910; see also M. A. Howe, *Science,* N.S. vol. xxxv. No. 909, p. 837 et sqq.

[71] *Comptes Rendus, Acad. de Sci.* 1910, p. 359.

In concluding this Address, I wish to express the hope that however incomplete the account I have given of the succession of forms may be, it will nevertheless help to stimulate an interest in these rock-building algæ and will encourage geological workers in this country to turn their attention to a hitherto neglected group of forms of great stratigraphical importance.

The following Papers were then read :—

1. *The Geology of the Country round Birmingham.* *By* Professor C. Lapworth, *F.R.S.*

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2. *Notes on the Igneous Rocks of the Birmingham District.* *By* Professor W. W. Watts, *F.R.S.*

3. *On the Spirorbis Limestones of North Warwickshire.* *By* George Barrow.

The typical Spirorbis limestone is a rather compact rock, usually grey and generally containing the small fossil *Spirorbis carbonarius*. The number of these varies greatly; at times several specimens may be seen in one fragment; often it is difficult to find any, and, so far as experience has gone at present, they are never abundant in this area. Though the dominant colour is grey, the rock is often buff and occasionally almost white.

The purest form of Spirorbis limestone occurs in masses of very variable size. The largest and most persistent bed is the Index limestone, which occurs roughly about 100 feet down in the Halesowen or Newcastle Group. This has often been confused with another and less persistent bed, lying about 100 feet further up and close to the base of the Keele Group. Other and less persistent bands have been met within the Keele Group, notably by Mr. Cantrill. In addition to these distinct beds, which can often be traced for some distance at the outcrop, if the ground be free of drift, there are lenticles varying in length from a few yards to a few inches, and at times only scattered nodules. These smaller patches were found during the great drought, when the old marl pits in the Halesowen Group were completely dried up. Advantage was taken of this to clean the pits out, laying the rock sides bare, when these minor occurrences of the limestone were exposed.

The limestones seem to have been built up of a series of films or layers, resulting from the evaporation of shallow sheets of lime-bearing water. When dried the film appears to have been cracked and more or less broken up, but re-cemented by later deposits of identical material; this in turn became broken up and re-cemented. The process was repeated till a bed several feet thick was at last accumulated. The whole rock thus comes to have a clean sharp fracture, though its fragmental character is easily seen on a freshly fractured face. In this form, best shown by the Index limestone, there is a minimum of material other than lime brought into the deposit. A rough test of the brecciated original fragments shows the limestone to be nearly pure and containing about 95 per cent. of carbonate of lime.

From this we pass to the type containing small fragments of other material, such as marl, and the cementing matrix is not merely calcite, a considerable proportion of mud and sand being present. In this the limestone fragments are somewhat rounded, having been transported for short distances. At times the fragments are locally heaped up and the bed attains a quite abnormal thickness. The band at or near the base of the Keele Group shows this character in the cutting in the mineral railway above Kingsbury; the fragments have been heaped up till it has locally attained a thickness of ten feet.

The extreme type is really a cornstone, or a sandstone more or less crowded with rolled fragments of Spirorbis limestone. It is doubtful in this case if any of the rounded fragments are formed *in situ*; the whole rock seems to have

been the result of flood action tearing up a deposit cracked by drying and transporting the fragments for some distance.

There is strong evidence to support the view that two at least of these limestones were formed over a large area; the Index has rarely been removed completely by this process; the one next above often has. How far the less persistent beds have been locally removed by subsequent erosion is at present an open question.

This mode of origin of the more impure, possibly of all the limestones, is supported by the character of the sandstones. These at their base often contain abundant pellets of marl, which from their form appear to have been sun-dried and so rendered sufficiently coherent to be capable of transportation for short distances without losing their cuboidal form. The phenomena suggest formation in shallow water, during a dry epoch, subject to sudden or periodical floods.

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4. *On the Stream-Courses of the Black-Country Plateau.* *By* HENRY KAY, *F.G.S.*

The Black-Country plateau is roughly outlined by the 400 feet contour line between Stafford, Worcester, Stratford, and Burton, and is identical with the anticline of the South Staffordshire coalfield, plus the north-western parts of Cannock Chase and the Warley-Barr area eastward. On its eastern and western sides are synclinal valleys opening to the Trent and Severn.

It is surrounded by a marginal hill barrier, and has large hill masses at Cannock Chase and the Clent region; while it is crossed by hill ranges from Bushbury to Barr Beacon, from Wolverhampton to the Lickeys, and from Quinton to Birmingham. The surface is thus divided into four interior basins, forming separate drainage areas. Save for the exits from these basins, the margin is broken in two places only. The chief physical feature is the possession of the crucial portion of the Midland watershed, which runs across the plateau from Wolverhampton to the Lickeys, and thence eastward along the southern margin.

Arterial drainage is supplied by the Trent and Severn, the former draining five-sixths of the plateau, and the latter receiving only the southward marginal drainage and that of the Stour basin.

The eastern syncline is occupied by the River Blythe-Tame flowing north. The watershed at the southern end of this valley has retreated northwards for four miles in post-glacial time.

The western syncline was formerly drained towards the Dee, and the head-waters of the Severn were originally around Kidderminster, the Clent range being united with the Enville hills further west. The principal outlet towards the Dee was by the Church Eaton Water, and the outlet into the Trent below Stafford not then in existence. This syncline is now drained northward by the Penk into the Sow and Tame, and southward by the Smestow-Stour into the Severn. Stream piracy is manifest near Wolverhampton.

Marginal streams are characterised by excessive activity, especially southward, notable examples being the Arrow and the Alne. The Arrow, however, represents the captured headwaters of an ancient river flowing through the Moreton Gap into the Evenlode, the pirate stream being the Warwickshire Avon, a strike river originally confined to the country west of Evesham. The watershed then ran southward from the Lickeys to the Cotswolds, being now represented by a long, narrow promontory reaching into Evesham and by Bredon Hill southward. Internal drainage is confined to the four basins. The Cannock Basin has now no trunk stream, its waters uniting near the exit below Cannock to form the Saredon Brook. Glacial modification is much in evidence, the south-eastern portion having formed a lakelet with gorge-like overflow through Walsall. The margin of this basin has twice been broached by marginal streams. The Tame Basin is triangular in shape, and formed by the union of two basins reaching back to pre-Triassic ages, a large buried stream-course existing at Moxley, whilst a very great valley is traceable upwards through Smethwick, Oldbury, and Blackheath. At this point two buried stream-courses are found, each filled with material transported from the Clent Hills. The inference is that this

marked the original source of the Trent, as the Upper Trent Valley appears to be of more recent date.

The Stour basin is likewise a combination. Streams descend south-west from Dudley to Stourbridge, and north-eastward from Clent to Halesowen. They are united by a succession of gorges four miles in length. This basin is a remarkable instance of extreme post-glacial denudation to a depth of 300 feet. The Halesowen streams represent the original headwaters of the river once flowing through Blackheath, Oldbury, and Smethwick.

The Rea basin possesses three eastward-flowing streams successively diverted N.N.E. through Birmingham by a stream working back along the Rea fault. Two of these were captured in pre-glacial time, the third in consequence of glacial lakelet overflow. The present thrice-notched ridge at King's Heath represents the pre-glacial land surface. The Middle Cole Valley is wholly post-glacial. The Lickey anticline has undergone elevation since the initiation of the Rea streams—*i.e.*, in post-Tertiary time. It is crossed by three waterworn gaps excavated *pari passu* with this uprise. The southernmost of these now drains into the River Arrow.

The Warley Barr area is a region of Tertiary uplift, across which rivers occupying the old pre-Triassic valleys have excavated deep channels. All other streams in this area are very youthful.

Conclusions.—The Trent drainage area has been subjected to excessive piracy and has steadily suffered loss. Its sole gain is that of the Penk at the expense of the Dee. The northern drainage is consequent on the formation of the South Staffordshire anticline, regarding the age of which it bears notable evidence. Speculations as to the former north-west extension of the Thames drainage must therefore be abandoned on reaching the area under consideration.

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5. *On the Formation of Rostro-Carinate Flints.*

See Appendix, p. 788.

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6. *On the Structure of the Lias Ironstone of South Warwickshire and Oxfordshire. By* EDWIN A. WALFORD, *F.G.S.*

The ironstone of South Warwickshire and North Oxfordshire is got wholly from the Middle Lias. The Northamptonshire ironstone of the Inferior Oolite may be traced in the Burton Dassett hills, where it passes into a useless sandstone.

Beds of the Middle Lias stone are seen in the quarries packed with curved and interlacing stems something like masses of annelid tubes. They lie upon the bedding plane. Other beds of the fine pentangular and smaller ossicles of the crinoidiæ range between. More rarely the round columnar stems of forms like *Apiocrinus* are found.

The author infers that the sea floor of the Middle Lias was a tangle of crinoid growth, stage above stage. The crinoid sea appears to have spread through the Midlands into Yorkshire. Occasionally are phases of invasion or dominance of shells of parasitic brachiopoda. Beds of *Rhynchonella tetrahedra* and *Terebratulæ* are interspersed in the 25 feet of the ferro-crinoid rock-bed.

The quarries and sections in the neighbourhood of Banbury show the several phases described.

In the Nodule Bed at the base of the ironstone series (zone of *Spirifer oxygona*) crinoidal conditions appear in segments and stem casts, mingled with large mollusca. Microscopic sections present plates and segments of crinoidiæ mingled with ferruginous oolitic grains of large size and fox-brown colour.

The superimposed bed, the Best Rag, has in sections smaller oolitic grains of olive-green iron carbonate with ovoid calicular plates of crinoids.

The Top Rag, a grey-green compact stone, is a tangle of crinoidal and other remains more or less broken into and converted into oolitic iron granules.

The Road Stone, the higher beds, shows its organic structure mainly destroyed and converted into the ordinary red oxide.

In 1896 I placed a short study on the making of the Middle Lias Ironstone of the Midlands before the Iron and Steel Institute, which appeared in their 'Proceedings.'

7. *Estheria* in the Bunter of South Staffordshire.[1] *By* T. C. Cantrill, *B.Sc., F.G.S.*

Records of fossils in the British Bunter are few in number, and some are open to doubt in respect either of their organic character or of the stratigraphical position of the beds that yielded them. Omitting those cases where the horizon formerly supposed to be Bunter has been corrected later and is now accepted as settled, the following appears to be a complete list, in chronological order of their discovery :—

1. *Dictyopyge catoptera* (Ag.), a small fish, from Rhone Hill, three miles S.E. of Dungannon, Co. Tyrone. Upper Bunter (f^3). With this was associated *Estheria portlocki*.
2. 'Annelid tracks' at Hilbre Point, Wirrall, Cheshire. Lower part of the Bunter Pebble Bed (f^2).
3. Plant-remains, referred to *Schizoneura paradoxa*, Schimper and Mougeot, at Sneinton Vale, near Nottingham. Uppermost bed of the Bunter Pebble Bed (f^2).

To these three older records can now be added the following new discovery[1] :—

4. *Estheria* cf. *minuta* (Alberti), from Ogley Hay, near Walsall, South Staffordshire. Bunter Pebble Bed (f^2).

These fossils were discovered in May 1911, when Mr. C. H. Cunnington and I were mapping the Triassic rocks bordering the eastern side of the coalfield. I suggested to my colleague that if fossils could be found anywhere in the Bunter they would most likely be discovered in the thin marl-bands occasionally interbedded in the predominant sandstones and conglomerates; and Mr. Cunnington's hammer was the first to reveal the specimens.

We obtained them from two thin bands of red marl in a disused sand-quarry at Ogley Hay, five miles N.E. of Walsall. The quarry forms a conspicuous excavation in the northern face of a sandstone hill, along the foot of which passes the Anglesey branch of the Wyrley and Essington Canal. The hamlet of New Town, on the Watling Street, lies 150 yards to the north of the quarry, while Ogley Hay Chemical Works stand 200 yards away to the south-east. Below a little drift gravel are exposed 22 feet of dull-red medium-grained soft sand-rock, in places false-bedded. Toward the bottom are two bands of red marl, about 1 foot 8 inches apart, the lower one being about 2 feet above the bottom. They nowhere exceed 9 inches in thickness. Both marl-bands yielded poorly preserved remains, determined by Mr. H. A. Allen as *Estheria* cf. *minuta* (Alberti).

The ground is coloured on the old series one-inch map (62 N.E.) as Upper Bunter (f^3); but the sandstones are coarser and duller in colour than the typical Upper Bunter of other Midland districts, and would more suitably be included in the outcrop of the Pebble Beds (f^2). The Triassic series dips at 3° to 5° toward E.N.E., in which direction the Pebble Bed sub-division appears to pass laterally into, and partly beneath, finer-grained and brighter-coloured sandstones that may be regarded as Upper Bunter. Above these follows the Lower Keuper Sandstone (f^5). There is thus no question as to the beds in the quarry being Bunter, and every ground for referring them to the Pebble Bed sub-division.

8. *Notes on the Flora and Fauna of the Upper Keuper Sandstones of Warwickshire and Worcestershire. By* L. J. Wills, *M.A., F.G.S., and* W. Campbell Smith, *M.A., F.G.S.*

A group of sandstones associated with green shales have been shown by Dr. A. C. Matley to form a more or less continuous belt in the Keuper Marls in Warwickshire, and to lie about 120-160 feet below the Rhætic. At the same horizon similar beds form an almost unbroken outcrop through Ripple, Longdon,

[1] Communicated by permission of the Director of the Geological Survey.

Pendock, and Eldersfield in South-West Worcestershire, and were probably once continuous with the sandstones of Inkberrow and Callow Hill, near Redditch.

Of the constituents, the thin-bedded sandstones are fine-grained, ripple-marked, and characterised by the presence of much calcareous matter and abundant rhombs of dolomite. The thicker-bedded sandstones consist mainly of grains of quartz, with felspar and the usual assemblage of heavy minerals in well-rounded grains; of these garnet is the most conspicuous. Close to the base of the group there is frequently a conglomeratic bed ('bone-bed'), composed of fragments of green marl, plants, bones, and teeth. Shales and steinmergel may occur with the sandstones.

We are able to describe for the first time from the English Trias examples of the foliage and scales of the female cone of a *Voltzia*, closely resembling *V. heterophylla*, of the Bunter of the Vosges, and to record new occurrences of *Voltzia, Schizoneura, Carpolithus*, and, possibly, *Yuccites*.

The plants are associated with indeterminable teeth and bones of Labyrinthodonts, and with fish remains, which are abundant in the 'bone-bed' and very rare at higher horizons.

Fish-teeth, hitherto described as *Acrodus? keuperinus*, are widely distributed, and prove, on microscopic examination of their internal structure, to be referable to *Polyacrodus* (Jaekel). Dorsal-fin spines and cephalic spines associated with these teeth probably belong to the same genus.

Phœbodus brodiei has been found frequently at Knowle. It, *Semionotus*, and *Ceratodus* have all been described before from these beds.

Cestraciont remains allied to *Polyacrodus keuperinus* are especially abundant in 'bone-beds' at the base of the Lettenkohle in Germany, and its presence may be regarded as evidence of estuarine conditions. Ceratodus, on the other hand, occurs frequently in the Rhætic, a deposit usually accepted as marine, but its only living ally inhabits some rivers in Queensland.

We have found *Thracia? brodiei* at Shelfield. This lamellibranch was described by Mr. R. B. Newton as a truly marine form, but it is only represented by rather obscure casts.

Estheria minuta, a form that is probably never truly marine, is practically ubiquitous, and occurs in both shales and sandstones.

The fauna and flora is thus seen to be a restricted one, though many specimens have been found, and their testimony on the origin and age of the deposit is inconclusive.

If we may judge from the lithology, the conditions which governed the formation of the 'skerry-belts' of Nottinghamshire and Leicestershire namely, the arrival of floods of fresh water—probably acted more persistently in the area under consideration, as a result of its greater proximity to land For not only are the beds very similar to the 'Skerries,' but in the 'bone-bed' or marl conglomerate we have positive evidence of littoral conditions.

Thus we are not dealing with a pre-Rhætic incursion of the sea, but with a littoral facies of the Keuper Marls, formed where the water was at times sufficiently fresh to support a small fish-fauna and in sufficient motion to move coarse sediments.

9. *Nodules from the Basal Ordovician Conglomerate at Bryn Glas, Ffestiniog. By* Professor W. G. Fearnsides.

FRIDAY, SEPTEMBER 12.

The following Papers and Reports were read :—

1. *The Development of the Midland Coalfields. By* Fred. G. Meachem, *M.E., F.G.S.*

Great advances have been made in mining since the first meeting of this Association in Birmingham in the year 1839. Women were then employed in the mines, also children under ten years of age, and all worked twelve hours

or more in the pit. To-day women are not allowed to work in a mine, and no youth under fourteen years, and the hours of labour are restricted by Act of Parliament to eight per day. Nearly all the mines worked in 1836 were shallow ones, and the output not more than 200 to 300 tons per week. The area of the coalfields was about as shown below, as against the present known and concealed areas of coal.

Year	S. Staffs	Leicester	Warwick	Salop	Total square miles
1836	70	20	10	20	120
1913	360	88	222	96	766

This last calculation includes the concealed coalfield between Chasetown, Aldridge, and West Bromwich on the west, and the Warwickshire and Leicestershire coalfields on the east, and also the concealed coalfield between Cannock, Essington, and Stourbridge on the east of the Coalbrookdale and Forest of Wyre coalfields on the west.

The output since figures are available is as follows :—

Year	S Staffs	Leicester	Warwick	Salop	Total in million tons
1865	10	$1\frac{1}{2}$	$\frac{3}{4}$	$1\frac{1}{2}$	$13\frac{3}{4}$
1912	$7\frac{1}{2}$	$2\frac{1}{4}$	$4\frac{1}{2}$	$\frac{3}{4}$	$15\frac{1}{2}$

This shows a great advance in industrial conditions and in economic geology, but the question of output does not show so great an increase; this I think is due not to fear that the concealed coalfields would not be profitable, but to the fact that some of the deeper mines have not proved remunerative. This is partly due to local conditions in the mines and also to the fact that the deeper coal costs more to get than the shallow coal, as regards actual working cost and the greatly increased capital needed, whilst the coal from both mines is sold in the same market, so that the shallow mine rules the selling price. As a few years pass by, and probably before the next meeting of this Association, the shallow mines will be exhausted, and the prices will be ruled by the deeper mines, with the usual economic results of increased prices in proportion to increased costs to get.

In the figures above, areas are included which were not thought of in 1836, but, as is fully shown by the report of the last Royal Coal Commission, 1905, coal will undoubtedly be found in the areas above named. The area between the South Staffordshire coalfield and the Leicestershire and Warwickshire coalfield will be found to be one continuous coalfield, with its deepest part at Lichfield, Sutton Coldfield, and Coleshill, but the basin rising to the south as a whole, the thick coal of Sandwell and Hamstead will split up into two or three seams, and under these conditions will be worked Longwall, with better commercial results. The area between the Staffordshire coalfield and Shropshire has been most vigorously investigated, and the proofs at Colwich, Huntingdon, Essington, Four Ashes and Baggerridge show that this area is going to be rich in coals of good quality and laid down under conditions that will allow of remunerative working.

On the Shropshire side very little has been done to extend that coalfield to the west of either the Coalbrookdale or the Forest of Wyre Coalfields, the edges of the Old Red Sandstone preclude any hope of extension, but in the Highley and Kinlet and Billingsley area it is most probable that future deeper sinkings will prove deeper coals than the two seams at present working, whilst the area to the east is full of promise. As soon as the Severn Valley fault, which is some 300 to 400 yards downthrow east, is crossed a new coalfield will be found, and I think the area between here and the old coalfield will be divided into two basins, with a Silurian anticline between them as proved by the Claverley boring.

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2. *On the Fossil Floras of the South Staffordshire Coalfield.* *By* E. A. Newell Arber, *M.A., Sc.D., F.G.S.*

The rich series of floras of the South Staffordshire coalfield has suffered much unfortunate neglect in the past. Several collections have, it is true, been made from time to time, but with very few exceptions they have never been described, and some of them are without proper records of locality and horizon. For such

trustworthy records as exist we are chiefly indebted to Dr. Kidston and to his memoir published as far back as 1888. The number of species, the exact locality and horizon of which are recorded, is at present as follows:—Keele Series 16, Halesowen Sandstone Series 0, ? Brick Clay Series (Old Hill Marls) 8, Productive Measures 27.

For some time past I have been endeavouring to extend our knowledge of the fossil floras of this coalfield, and I have been fortunate in receiving the active co-operation of several geologists resident in Birmingham and the neighbourhood, who have most kindly formed collections from particular areas, and forwarded the specimens to me for examination and description. In this way the material which I have myself been able to collect has been greatly extended. My thanks are in particular due to Mr. H. Kay, F.G.S., Mr. W. H. Foxall, F.R.G.S., Mr. W. H. Hardaker, M.Sc., and Mr. L. Jackson for their enthusiastic co-operation.

Attention has been chiefly concentrated so far on the floras of the Brick Clays, and of the lowest beds of the Productive Measures on or about the horizon of the Bottom Coal. A considerable number of species have been obtained from both horizons, of which some are new records both to the coalfield and to Britain. This work is still in progress. Information has also been obtained as to the horizon and localities in which the petrified specimens, long known from this coalfield, occur, such information having been lost for many years past.

In addition the first fossil plants from the Halesowen Sandstone Series have been unearthed by Mr. Kay, and here again both petrifactions and impressions occur.

It is hoped that in course of time it will be possible to trace the floras systematically from the lowest to the highest beds of the coal measures of this coalfield. The material, however, has to be obtained as opportunity offers, and this preliminary note is intended merely to indicate the present progress of the work.

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3. *On the Correlation of the Leicestershire Coalfield.* *By* Robert Douglass Vernon, *B.A., B.Sc., F.G.S.*

The following is a preliminary account of a study in the correlation of the coalfields of the eastern portion of the great Midland coal basin. The area in question includes the Derbyshire and Nottinghamshire coalfield in the north, the Warwickshire coalfield in the south-west, and the Leicestershire coalfield which lies midway between the two. It is with the latter that we are here chiefly concerned. The Carboniferous rocks of Leicestershire include Carboniferous Limestone, Limestone Shales, Grits and Sandstones that have been referred on lithological evidence to the Millstone Grits, and, lastly, the Coal Measures. Such a sequence at once suggests a correlation with the Derbyshire and Nottinghamshire type, but the presence of unusually thick seams of coal which split towards the north favours a comparison of the Middle Coal Measures of Leicestershire with those of Warwickshire. Finally, in the complete absence of the Transition Series and Upper Coal Measures and the presence of a complex fault system, the Leicestershire coalfield stands quite apart from either of its neighbours.

For the detailed correlation of the Upper Carboniferous of these tectonic basins we have several independent criteria, both physical and palæontological, but strong theoretical objections may be urged against the use of physical criteria alone, and in practice it was found to be impossible to use either the important sandstones or the seams of coal in the correlation even of the eastern and western portions of the Leicestershire coalfield itself.

The problem was then attacked from the palæontological side. Fossil plants proved of relatively little value in the sub-division of the Leicestershire sequence, because the lowest and the highest plant-bearing horizons both appear to fall within the Middle Coal Measures. The freshwater lamellibranchiata (*Carbonicola* and its allies) were equally unsatisfactory, so that the work finally resolved itself into a search for Marine Beds and an attempt to lay down their outcrops on the six-inch maps.

Of the three more or less distinct districts into which the Leicestershire

coalfield may be divided, the Central or Ashby area of so-called unproductive measures yielded no fossils, either plant or animal, and the age of the beds, whether Lower or Middle Coal Measures, remains an open question. The Eastern or Cole Orton area presents serious difficulties to the collector, being for the most part a concealed coalfield worked under a thick Triassic cover, and the results obtained were merely of local interest. Attention was finally concentrated on the western or Moira area, where the sequence is more complete than in the rest of the coalfield, and exposures are much more numerous. Many fossiliferous horizons were discovered, which yielded a rich flora, several rare Crustacea, some fragmentary fish-remains, numerous freshwater lamellibranchiata, and above all an abundant marine fauna from several different horizons and many localities. Unfortunately, no indication of the well-known Ganister Coal Marine Bed (Alton Coal of Nottinghamshire) has yet been found in Leicestershire.

The thickest Marine Bed, which also has the richest fauna, occurs in the higher portion of the Middle Coal Measures about 260 yards above the Moira Main Coal; it crops out at many places in the Moira, Swadlincote, Church-Gresley, and Woodville district, and the outcrop has been laid down on the 6-inch scale.

Such mapping is of value since for want of an index bed it has hitherto been impossible to map any seam of coal above the Main Coal owing to the variable character of the beds in the higher portion of the Coal Measures, and the structure of this part of the coalfield was, therefore, imperfectly understood. Using this Marine Bed as an index bed, we can now fix the position in the sequence of the Moira Sandstones and Grits and of the valuable series of pot, pipe, and fireclays on which the prosperity of this district so largely depends.

The main interest of this Marine Bed is that in stratigraphical position and in faunal contents it is comparable with the Gin Mine Marine Bed of the North Staffordshire coalfield, with the Mansfield Marine Bed of the Yorkshire and Nottinghamshire coalfield, and with the Pennystone Ironstone Marine Bed of Coalbrookdale.

The following is a correlation of the Productive Coal Measures of the East Midland coalfields, based upon the chief marine transgressions:—

Yorkshire and Nottinghamshire Coalfield		West Leicestershire Coalfield	Warwickshire Coalfield	
	Mansfield Marine Bed	Pottery Clay Marine Bed	Doubtful	
	Strata, 930 feet	Strata, 750 feet	Strata, thickness unknown	Middle Coal Measures.
Middle and Lower Coal Measures.	Marine Bed 300 feet below the Top Hard coal	Marine Bed above the Main Coal	Marine Bed above the Seven-foot Coal	
	Strata, 1,600 feet	Strata, thickness unknown		
	Marine Bed above the Alton (Ganister) coal	Doubtful	Absent	

In conclusion, it was shown that in colour, mode of weathering, and other characteristics these Marine Beds are in every way comparable with modern 'Blue Muds.'

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4. *On Systems of Folding in the Palæozoic and Newer Rocks.* *By* GEORGE BARROW.

In a paper published by the Geologists' Association the author has given a brief outline of the nature of the crystalline area of the Highlands and shown that it consists of three great lenticular masses of thermally altered rocks. It

is further shown that the outer and uncrystalline margins of these masses all trend roughly north-east and south-west. The best known is that forming the south-eastern margin of the crystalline area, which the author has followed, where present at the surface, almost the whole distance from Stonehaven, on the east coast of Scotland, to Omagh in the north of Ireland. Recent work suggests that this margin is also present on the west coast of Ireland.

This outer margin of crystallisation is not confined to Scotland; it is also present in Anglesea, where the margin of the crystalline *massif* is seen along a portion of the Menai Straits. It also occurs in the Isle of Man, where the old rocks are identical with those of the lower aureoles of thermometamorphism in the southern Highlands. In both cases the trend of this outer margin is the same—north-east and south-west. Wherever this margin can be examined it has been found to be a great line of resistance, and the folding in the adjacent palæozoic, and, at times, even newer rocks, is found to be parallel to it; it is in fact the cause of the strike of the folding; under earth-stresses the softer rocks have buckled up against a great resisting crystalline mass.

Thus, strictly speaking, there is no such thing as a Caledonian Movement; there are a series of resisting masses with parallel margins; the folding in North Wales is determined by the Anglesea Archæan Rocks; Caledonia has nothing whatever to do with it.

If, now, we turn to the area in the south of Britain, we find another system of folding; this, too, the author believes to be due to a similar cause. The outer margin of the old crystalline rocks in Cornwall seems to be roughly east and west; it certainly is not north-east and south-west. It now remains to do in the north-west of France what the author has done in North Britain—*i.e.*, to trace out the outer margins of crystallisation and prove that the so-called Hercynian system means simply that the boundaries of the resisting crystalline masses, against which the newer rocks buckle up, now trend east and west. If these facts are once grasped we have an explanation of the local departure of the strike of the folding in the north of England; the lines of resistance locally depart from their usual trend and the subsequent folding does the same.

5. *The Division between the Lower and Upper Avonian. By* Dr. A. Vaughan.

6. *The Harlow Boulder Clay*[1] *and its Place in the Glacial Sequence of Eastern England. By* A. Irving, *D.Sc., B.A., and* P. A. Irving, *B.A.*

(1) In the light of Professor Bonney's Presidential Address at Sheffield (1910) and the known intersection of the East Anglian chalk range by the pre-glacial Stort-Cam Valley (well-sections at Elsenham and Quendon), it is submitted that the facts recorded last year point legitimately to the conclusion that the (roughly) East and West line of high country about two miles south of Harlow (Essex) represents the *terminal moraine* of the southernmost prolongation (through the Elsenham Gap) of the 'inland-ice.' Its till-like character, the contained fossils and erratics (with the failure to detect any rock-fragments of Scandinavian origin), suggest that the Mercian ice-sheet was the confluent mass of two contributing sheets, one on either side of the Pennine mountain-chain, with smaller contributory glaciers from that region, sweeping the Midlands of *débris* from such districts as Charnwood, during the early Pleistocene maximum (alpine) elevation of the more northerly portions of the British area. Such considerations further suggest synchrony between the deposits (so similar in character) at Harlow, Cromer, and Saffron Walden; antedating the 'Chalky Boulder Clay' of East Anglia by the interglacial period of the glacial shingle (with remains of *Hippopotamus, Elephas antiquus, Bos primi-*

[1] *B.A. Reports*, Dundee Meeting (1912), pp. 132 ff.; *Nature*, June 20 and August 22, 1912.

genius, *Equus*, *Cervus megaceros*, and Chellean (?) implements), which now fills the preglacial channel in the chalk to a proved depth of 170 feet.[2]

(2) The *Chalky Boulder Clay* of the plateau (as distinguished from its 'rubble-drift derivatives) is well defined on either side of the upper valley of the Stort at altitudes of 240 feet to 270 feet (O.D.), maintaining a pretty constant character in numerous grave-sections, well-sections, and open excavations. Its general facies and composition differentiate it from the Harlow Till, and from that which occurs at lower level in the valley, 220 feet to 230 feet (O.D.).

(3) The *Valley Boulder Clay* consists at Thorley of a compact silty deposit, devoid of chalk detritus, elongated erratics often standing erect in it, presumably dropped from stranded ice-rafts. In the Thorley gravel-pit good sections (transverse to the valley) have shown some seven feet of such a boulder clay intercalated with contorted gravels, including 'gravel-boulders' (Bonney), originally deposited as frozen masses, and showing evident causal connection with the contortions.[3] The whole deposit overlies the sandy interglacial current-bedded gravel (12 feet), with included erratics, seen in greater force in the more extensive gravel-pit on the other side of the valley, forming an interglacial series younger than the plateau Chalky Boulder Clay but older than the contorted gravel series (with intercalated Boulder Clay) of the valley. (See section with altitudes determined by 'levelling,' fig. 1 of circular of the Geologists' Association for excursion on June 21, 1913.)

(4) In some recent deep well-sections (piercing the chalk) a distinction can be drawn between the Chalky Boulder Clay and the Blue Boulder Clay (=Harlow Till) with a zone of 'rubble' between them. Horizon of the Latton and Hockerill gravels.

From the above data the following tentative correlation is put forward for the consideration of geologists:—

Peaty Alluvium (*post-glacial*) of the Stort and the Lea, &c.: finer 'rubble-drift' of lower valley-flanks.

(iv) *Valley Boulder Clays and Contorted Gravels*: coarser 'rubble-drift' of higher valley-flanks: *E. primigenius* and *Equus*, palæoliths [Hessle Boulder Clay?] (= 'Wurm'[4] or 'Mecklenburgian'[5]).

[Sands and gravels (in part) of Anker's and Rippon's pits, near Peterborough.][6]

Third Interglacial: current-bedded fine gravel and sand with erratics.

[Sand and shingle, with Mammoth, &c., and erratics filling old river-channel at Fletton.][6]

(iii) *Chalky Boulder Clay of East Anglia*: Stortford and Thorley plateau (= 'Riss'[4] or 'Polandian'[5]).

Second Interglacial: glacial shingle filling the older Stort Valley, with extinct Pleistocene mammalian remains and very early palæoliths; sand and shingle of the Latton pits to the S. of Harlow.[7]

[Interglacial sands of the Gipping Valley.]

(ii) *Harlow Till* (='Mindel'[4] or Saxonian[5]); Saffron Walden and Cromer tills.

First Interglacial: ('Norfolkian'[5]) not delimitable from (i).

(i) *Herts Plateau-Drift* (= 'Gunz'[4] or 'Scanian'[5]) of the Stortford Waterworks.[8]

The 'Great Ice Age' would be represented by (ii) and (iii) in the above scheme; its gradual incoming by (i), and its gradual outgoing by (iv).

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[2] *B.A. Reports*, Portsmouth Meeting (1911), pp. 521-2.

[3] Photographs (slides) by Mr. H. G. Featherby, of Bishop's Stortford.

[4] Penck and Brückner.

[5] Professor J. Geikie.

[6] See paper read in Section C last year; printed *in extenso* in the *Geol. Mag.* for September 1913.

[7] These underlie the Chalky Boulder Clay in the pit-face for some 200 yards, and contain many rolled and weathered erratics from the Harlow Till; the 'Schotter' is mainly composed of such material. The extra weathering and rounding differentiate them as a series from those found in the Till itself.

[8] See *Mem. Geol. Surv.* vol. iv., p. 449.

7. *The (Lower?) Carboniferous Grits of Lye, in South Staffordshire. By* W. Wickham King, *F.G.S., and* W. J. Lewis, *B.Sc.*

In the 'Geological Magazine,' Dec. 4, Vol. ix. (1912), p. 437, we announced (*inter alia*) that *purple* beds of Lower Old Red Age existed at Saltwells. Since then we have ascertained that two miles to the south, at Lusbridge Brook, Lye, below the Thick Coal, Carboniferous Beds are exposed for a thickness of nearly 400 feet as against about 200 feet at Saltwells. These basal beds are difficult to interpret.

The succession below the Thick Coal in Lusbridge Brook is thus: (*a*) Various Clays and Coals 280 feet; (*b*) Conglomerate 27 feet; (*c*) Red Clays (Plants) and White and Yellow Clays, in which are embedded many pieces of quite unworn pink calcareous Grits, and at base Limestone Grits and a Conglomerate, thickness 40 feet; (*d*) White, Red and Yellow Clays. (*d*) is only exposed for about 30 feet. Total below Thick Coal 377 feet. Mr. F. G. Meachem has kindly given to us data proving that the beds down to the base of (*b*) are the same thickness in the Freehold Pit, Lye, and that there, below (*b*), they pierced Red Marls for 150 feet.

The interesting zones are those in which the Limestone and pink Grits occur. Broken fossils occur in the Limestone Grit, which is made up largely of angular pieces of Limestone. In the Conglomerate (*b*) a pebble 18 inches in diameter of highly calcareous grit containing *Calamites varians* has been found, which is probably another type of this Limestone Grit. A precisely similar calcareous grit was found *in situ* at or below (*b*) in the Freehold Pit, and above (*c*) a nearly similar type occurs in the form of gigantic slabs 2½ feet thick in the Lye Cemetery.

Encrinite débris only can be identified in the pink Grits. We found in the Clays (*c*) a minute fragment of a Brachiopoda with a straight hinge-line.

Lithologically the Lye Grits are identical with the so-called millstone Grits of Titterstone Clee Hill (sixteen miles to S.W.), in which Lower Carboniferous plants occur; but until further evidence is found, Mr. Dixon suggests these Clee Grits be given a non-committal designation. At a later stage it was suggested to us that the Lye Grits may be the base of the Middle Carboniferous.

In the Conglomerates there is distinct evidence of Inter-Carboniferous denudation which removed in places, as at Saltwells, Coal Measure Ironstone (*Neuropteris*), Coal Seams, Grey Limestones (*Productus* sp.?), and Limestone and Pink Grits.

In 'Q.J.G.S.,' Vol. 55 (1899), p. 123, Mr. King showed that all the pebbles in the Permian Conglomerates of the Severn Basin are referable to a local source, except only those of Lower Carboniferous Age. The last-mentioned pebbles contain *Syringopora* and *Caninia* of probably D^{2-3} and Pendleside types. Some of the pebbles are identical lithologically with the Limestone and Pink Grits now found at Lye.

In Permian times the Lower Carboniferous Rocks provided, from original and derivative local sources, much of the material in the Permian Calcareous Conglomerates.

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8. *On some of the Basement Beds of the Great Oolite and the Crinoid Beds. By* Edwin A. Walford, *F.G.S.*

Sowerby, in Vol. 1 'Mineral Conchology,' describes a brachiopod now known as *Rhynchonella concinna*. It is figured on T. lxxxiii. 6 from Aynhoe in Northamptonshire. A note of a quarry in the Great oolite made by the writer in 1883 fixes probably the source of Sowerby's shell—

Aynhoe Allotments Quarry.

	Ft.	In.
1. Humus	1	3
2. Whitish Marl	1	3
3. Marl crowded with *Rhynchonella concinna*, *Ostrea Sowerbyi*, *Natica*, *Modiola*, *Pholadomya*	2	6
4. Shelly Limestone, false bedded	1	9
5. Grey Marl	2	1
6. Limestone, whitish: top course	1	6

The Geological Survey found its stratum to be a convenient line of demarcation, as it rested upon a base of limestone graduating into the Stonesfield series.

The discovery of other strata on the borders of East Oxfordshire and West Oxfordshire necessitates the division of the Great Oolite and the separation of the new beds proposed to be classed as Sub-Bathonian. The old survey lines are thus sustained. The sequence suggested is as follows :—

UPPER GREAT OOLITE.—1. *Terebratula maxillata* beds. 2. *Calcaire à Echinodermes.*

LOWER GREAT OOLITE.—1. Striped Limestones. 2. *Rhynchonella concinna* beds. 3. Stonesfield Slate.

SUB-BATHONIAN.—1. Striped Limestone and Crinoid beds. 2. Neæran series. 3. Striped Crinoid Marls. 4. Chipping Norton Limestones.

The new railway (Aynhoe and Ashendon) is cut along the divide between the Cherwell and Ouse rivers. The missing Sub-Bathonian series of the West lands were brought to view. Prominent there were White Calciferous Limestones and Striped Marls and Limestones. The author found the chalk-like limestone to be crowded with the decayed heads of large crinoids of which it was made. Above it passed into a blue crystalline limestone, here and there; a packed mass of the brachial joints of the crinoids. At the base of all was the stratum of black vertical stripes (the striped beds), the place of crinoid column and rootlets filled with carbonaceous granules from dark beds above. The beds are now known to be marine, not estuarine, as previously described. Sections of the chalk-like limestone showed a pavement of discs of the crinoid (*Apiocrinus*) calyx.

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9. *The Value of a Knowledge of the Rock Soil Distribution of Plants in Tracing Geological Boundaries. By* A. R. HORWOOD.

During the last ten years the new science, Ecology, has made great strides, and one branch of it—that which deals with the distribution of plants upon different soils—has become recognised as a sure means of determining the type of vegetation which characterises each soil. Conversely, the type of vegetation is an indication of the soil.

Whilst the geological formations, with the sub-divisions, are numerous, the soils may be roughly divided into six classes, and the influence of lime in the soil upon plant distribution is especially marked.

These facts now systematically studied have an important bearing upon geology, more especially in the delineation of zones and sub-zones.

It is well known that certain formations, such as the coal measures, Keuper, Rhætics, Lias, &c., have intermittent thin bands of limestone, &c., which are not always to be seen in the field, in section or otherwise, and difficulty arises in tracing them across country for this reason.

In a similar way the existence of irregular beds of sand in glacial deposits is often obscured by vegetation or other causes, and their existence is frequently a matter of conjecture. As these details of mapping are of importance, especially to the builder, agriculturist, and horticulturist, and economic geology is to-day a great factor in survey work, any accessory aids that can be rendered by the ecologist are worthy of the consideration of geologists.

Moreover, ecology has advanced so far already that surveys of several regions have been made and exact vegetation maps published, so that it is expected that this science, which is of such importance from the economic, as well as the stratigraphic, standpoint, will have shortly to be established upon a national basis, and ecological surveys carried out by the State. This necessity arises primarily from the purely ecological value of the work, and since ecology and geology are interdependent, there is additional reason for urging that the former be recognised as fully as the latter as of national importance.

It is therefore suggested that till this is accomplished geological survey work should be carried out in conjunction with ecological surveys, or, at any rate, that those at work in each district upon ecological surveys be asked to co-operate, where required, with geological surveyors, especially in those areas where this co-operation would be of great assistance in tracing boundaries of local beds.

Further, it is suggested that a definite effort should be made to accomplish

the appointment of Government ecological surveys by those already officially in charge of geological work, in view of the assistance each science can render the other. Whilst emphasis is here laid on the value of ecology to the geologist, equal value is rendered by the geologist to ecology. The author illustrates these principles by examples from an ecological survey of Leicestershire, where he has found that a knowledge of rock soils and plant distribution has supplemented the evidence of geological data. It is thought that geologists generally may not be fully aware of what is being done in a different field, and the significance of rock-soil work to them may have been overlooked.

10. *Report on the Erratic Blocks of the British Isles.* See Reports, p. 145.

11. *Report on the Investigation of the Igneous and Associated Rocks of the Glensaul and Lough Nafooey Areas, Co. Galway.*—See Reports, p. 150.

12. *Interim Report on the Preparation of a List of Characteristic Fossils.*—See Reports, p. 150.

13. *Preliminary Report on the further Exploration of the Upper Old Red Sandstone of Dura Den.*—See Reports, p. 150.

MONDAY, SEPTEMBER 15.

The following Papers and Reports were read :—

1. *The Geology of the District between Abereiddy and Pencaer, Pembrokeshire. By* A. Hubert Cox, *M.Sc., Ph.D., F.G.S., and* Professor O. T. Jones, *M.A., D.Sc., F.G.S.*

In an introductory paragraph the authors referred to the work of previous observers, namely, Hicks, Reed, Elles, and Elsden, and to the visit of the Geologists' Association during Easter, 1910, when results were obtained which suggested that this area required re-investigation. Examination by the authors has proved that the apparent sequence is extremely complicated by strike-faulting, and instead of Llandeilo and Bala rocks, as previously supposed, Arenig and even Cambrian rocks form large areas of the coast.

Part I. Abereiddy Bay to Pwll Strodyr (A. H. C.).

The ground is occupied by the under-mentioned beds, the stratigraphical order of which is, so far as known, as follows :—

Bala	Limestone of Eastern Quarry, Abereiddy = Mydrim Limestone of Carmarthenshire.
Llandeilo . . .	Lower *Dicranograptus* Shales = Hendre Shales of Carmarthenshire.
Llanvirn . . .	*Didymograptus Murchisoni* Shales.
	Didymograptus Murchisoni Volcanics (including the Abereiddy Ash, and Llanrian lavas).
	Didymograptus bifidus Shales.
Arenig	*Tetragraptus* Beds—dark slates.
	Porth Gain Beds—grits and slates with *Orthis calligramma*, var. *proava*.
	Abercastle Beds—sandy mudstones with *Ogygia selwyni*, &c.
	? gap.

Doubtful Age . .	{	Castell Coch Beds—cleaved blue-black mudstones. Ynys Castell Beds—siliceous mudstones and cherts. Ynys Castell grit and breccia.
		? break.
Lingula Flags . .	.	Flags and laminated quartzites with *Lingulella davisii.*
? Menevian . . .	.	Slates near Abercastle with *Agnostus* sp.

The 'Middle Llandeilo' of Hicks' classification has been found to include the Lower Dicranograptus Shales and the succeeding limestone; that is, actually more than the Llandeilo formation as now defined. The 'Upper Llandeilo' includes various Lower Llanvirn and Arenig beds; the affinities of the other rock-groups are briefly discussed in the paper. Lingula flags occupy much of the adjoining inland district.

References were made to certain 'intrusive rocks and their relation to the adjoining sediments.' The detailed mapping of the area is now in progress.

Part II. Pwll Strodyr to Pencaer (O. T. J.).

The following rock-groups are represented in probable descending order:—

Lower or Middle Arenig	Pwll Deri Slates	Cleaved dark slates with extensiform graptolites.
? Lower Arenig	Aberbach Quartzite group, probably equivalent to the quartzites of Trwyn Llwyd and possibly of Pwll Strodyr	Quartzites with thin dark shales.
Lingula Flags	Mynydd Morfa group	
Doubtful Age	Pwll Crochan group	Dark slates with obscure fossils, probably Menevian. or Upper Lingula Flags.
? Solva	Llech Dafad group	Quartzites, green and purple sandstones; obscure fossils.

The age and relationships of the various groups were briefly discussed, and reference was made to certain intrusive rocks which occur among the lower groups.

In view of the great thickness of some of the groups and of the bearing of their age upon the igneous rocks of Pencaer and Strumble Head it is proposed to map the area in detail.

2. *The Relation of the Rhiwlas and Bala Limestones at Bala, North Wales. By* Dr. GERTRUDE L. ELLES.

The difficulties in the interpretation of the succession in the Bala district appear to be due largely to the impersistent nature of the limestones and their inconstancy as to horizon.

The succession is as follows:

Hirnant Series . . .	{	Hirnant Limestone (impersistent). Hirnant Flags and Mudstones. Rhiwlas Limestone (impersistent).
Bala Limestone Series .	{	Bala Limestone (impersistent). Calcareous Ash. Mudstones. Coarse Ash. Mudstones and flags with thin impersistent Limestones. Ash. Sandy flags, with occasional impersistent Limestones. Ash (in N. part of area only). Sandy flags becoming shaly towards base.

The Rhiwlas Limestone is an impersistent limestone at the base of the Hirnant Series, and is found typically only in the northern part of the area. The Bala Limestone is not developed as a calcareous bed in the northern part of the

area, but is somewhat more persistent as a definite band in the southern and eastern portions of the district. The true relation of these horizons to each other is seen in the type section at Gelli Grin, where the Bala Limestone at its maximum thickness is overlain by light-coloured, pasty mudstones containing a typical Rhiwlas Limestone fauna. The fauna is not nearly so rich in individuals as that of the Rhiwlas Limestone itself, but all the more important genera and species seem to be represented. Confirmatory sections are also seen east of the fault near Gelli Grin farm, and also on Bryn Cut.

3. *Plant Petrifactions in Chert and their bearing on the Origin of Fresh-water Cherts. By* MARIE C. STOPES, *D.Sc., Ph.D.*

The author described, and illustrated with photos, petrifactions of plants in the fresh-water cherts of Lulworth (Purbeck) and Asia Minor (Tertiary). The author drew special attention to the Asia Minor cherts, which are remarkably interesting and contain well-preserved plant debris. These were described by Mr. Haydon in his Presidential Address to the Liverpool Biological Society, but his work seems not to have reached most geologists and palæobotanists. The cherts contain beautifully preserved pollen grains, fungi, stem debris, &c.; and the existence of these delicate soft tissues so well preserved suggests that Sollas' view of flint formation can only be applied with caution to these fresh-water cherts.

The author drew attention to the recent 'Sapropel' observed by Potonié, and the likeness it has to the debris in the Asia Minor chert; concluding that the chert may be taken as practically pure petrified 'Sapropel,' a phenomenon which must interest those who are concerned with the methods of plant petrifactions.

4. *Critical Sections of the Cambrian Area called The Cwms in the Caradoc-Comley Region of Shropshire. By* E. S. COBBOLD, *F.G.S.*

The work of excavation of critical sections in the Cambrian rocks of Shropshire has been continued by the writer at intervals during the past year, and has furnished palæontological proofs of the prolongation of the Lower and Middle Cambrian rocks of Comley into the Cwms area to the south. The sections opened up confirm and amplify those excavated in previous years.

Excavation No. 53 supplies details of the upper portion of the Wrekin Quartzite and the lowest part of the Lower Comley Sandstone, near the base of which three fossiliferous bands are found, yielding species provisionally referred to *Kutorgina, Hyolithus, Hyolithellus,* and *Archæocyathus.*

Excavation No. 54 exhibits a section of the junction of the Middle and Lower Cambrian beds, which is very closely comparable with those of the Quarry Ridge at Comley.

The beds in descending order are as follows :—

e. Shale with Grit Bands = The Quarry Ridge Shale, top not seen	4 feet
d. Hard, ringing, glauconitic Grit = The Quarry Ridge Grit . .	28 ,,
c. Conglomerate = The Quarry Ridge Grit, conglomeratic portion	9 ,,
b. Dark Grey, Purplish and Red Limestones = The Black, Grey, and *Olenellus* Limestones of Comley	about 4 ,,
a. Green, Micaceous Sandstones, with Spotted Bands = The Lower Comley Sandstone; base not seen	10 ,,

The conglomerate *c* is plentifully charged with fragments of the Black and other Lower Cambrian Limestones, and it is now proved for the first time that the Black Limestone must be grouped with the Lower Cambrian.

The surface of the solid Black Limestone is coated with a phosphatic (?) skin, and a similar deposit in the Comley Quarry has within the last two or three years yielded recognisable fragments of *Paradoxides* sp. and *Dorypyge Lakei* Cobbold. The black skin must, therefore, be regarded as the lowest deposit of the Middle Cambrian age that is known in the district.

Among the numerous fossil fragments that occur in the Lower Cambrian Limestones of this excavation the following have been identified:—

Anomocare (?) *pustulatum* Cobbold, *Callavia Callavei* Lapworth (?) *Microdiscus Attleborensis* S. and F. sp., *Protolenus* sp., *Kutorgina* sp., *Linnarssonia* (?) sp.

Excavation No. 55 exhibits a faulted junction between the Middle and Lower Cambrian, the hard, ringing Grit (beds *d* above) being brought into contact with the Green, Micaceous Sandstone (beds *a* above).

Excavation No. 56 proved the existence of both the Quartzite and the lower part of the Lower Comley Sandstone at another point in the area.

A section constructed embodying the results of these excavations provides evidence that the Lower Comley Sandstone has a thickness of about 480 feet.

The paper was accompanied by a sketch-plan showing the exact positions of the excavations, and a section through the Comley and Cwms areas indicating the general relations of the deposits to one another and to the superincumbent younger rocks.

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5. *Flint and its Genesis. By* A. Irving, *D.Sc., B.A.*

A. Lithology of Flint.

1. Flint, intrinsically a member of the family of minerals[1] having the common characteristic (as compact minerals) of consisting essentially of silica (SiO_2) with slight traces of accessory ingredients (commonly iron and carbonaceous matter, more rarely potash, alumina, and lime), has closer affinities with chalcedony, opal, menilite (retinite), holding a certain amount of water in combination, as distinct from mechanically contained water. (Fuchs, Bischoff, Rammelsberg, Wislicenus referred to.)

2. *Iron staining* referred to well-known chemical sequence[2] of (i) dissolved protosalts of iron penetrating the flint differentially according to molecular structure; (ii) the peroxidation of the iron base with the breaking up of the acid constituent of the salt on the access of free oxygen, more fully discussed by the writer elsewhere. Reference to the excessive iron-staining of the Sussex flints (Piltdown) as a demonstration of this in Nature's laboratory.

3. *Patination* of fracture-surfaces considered as an incipient stage of *devitrification,* involving the metatropic change from the vitreous to the stony or porcellanous molecular structure of the mineral.[3]

Evidence forthcoming of the action of heat and sunlight under desert conditions in promoting devitrification (*quâ* crystallisation); 'Réaumur's porcelain' referred to again; also the lithological change observed in flaked flints brought from the Egyptian desert[4] *Accessory minerals* in the flint important factors of devitrification. Work of Stas[5] on the action of acids upon different kinds of glass; action of humus-acids on glass buried for a long time in the soil; formation of crystalline masses (richer in lime and magnesia[6]) in glass during the incipient stage of congelation—all throw light on this occult question. Reference to 'Report on Diffusion in Solids' by Dr. C. H. Desch (in the last Report of the British Association, Dundee Meeting, 1912), 'diffusion in glasses and devitrification.' Any attempt to classify flints according to age by mere 'patination' or iron-staining, regardless of (*a*) the variations in secondary character of the flints, (*b*) the physical conditions to which they may have been exposed at different periods of their history, appears to be in the highest degree empirical.

4. *Etching* is referred to unequal responsiveness to the action of natural

[1] Kalkowsky, *Elemente der Lithologie* (xviii., Familie der Kieselgesteine).

[2] A. Irving, (*a*) *Brit. Assoc. Reports,* Southport Meeting (1883), Sect. C; (*b*) *Proc. Geol. Assoc.* vol. xii. pp. 227 ff.—'Organic Matter as a Geological Agent.'

[3] A. Irving, *Chem. and Phys. Studies in Metamorphism* (Longmans, 1889), § iii., and App. i.

[4] Presented to the writer at the time by Captain H. G. Lyons, R.E., F.R.S.

[5] Percy, *Metallurgy* (vol. i.) quoted by the writer (*op. cit.*).

[6] Percy, *op. cit.*

solvents, resulting from the allotropic modifications of the silica, with the presence or absence of accessory bases such as iron and lime. 'Azo-humus-salts,' resulting from the arrested oxidation of *nitrogenous* organic matter, the most common natural solvents for silica.[7] (Examples of such corrosive action submitted.) Free humus-acids (from decay of *non-nitrogenous* organic matter) probably act only upon such constituents of the flint as contain traces of bases. The author's demonstration of such action years ago referred to.[8] Flints embodied in pumiceous volcanic tuff etched by the direct differential action of alkaline solutions upon the allotropic modifications of the silica.

5. Natural agencies concerned in the *fracture* of flint discussed : (*a*) differential movement of the chalk strata, (*b*) percussion, (*c*) frost-fracture. Any empirical deductions from fracture experiments on flint must take into account the variations in lithological character, requiring laborious use of the chemical balance. Reference to the recent work of Mr. F. N. Haward and Mr. Hazzeldine Warren, and to the fracture effect in differential earth-movements of heavily-weighted gravel, schotter, scree, talus, &c.; tough quartzite pebbles undergoing 'scarring' instead of fracture, as seen in the Bunter pebble-beds of Budleigh Salterton and Sutton Coldfield.

6. *Disruption* of hollow flint-nodules into multiform fragments by the expansive force of freezing water, compared with the actual case of the disruption of a bomb-shell (walls 1¼ inch thick) at Wellington College (1881) by the same agency.[9] A striking instance of this submitted exhibiting strain-cracks crossing the nodule, from which a considerable portion had been split off in its disruption; the cortex having become opalescent, without iron-staining, owing to the absence of organic solvents, although the flint was obtained at a depth of 11 feet from an exceedingly ferruginous post-glacial deposit.[10] 'Flaking' (as a phase of disruption) may result from expansion due to heat alternating with rapid cooling owing to powerful radiation under desert conditions.

7. Normal flint being about as hard as quartz (=7), its fracture surfaces may be *scratched* by grains of zircon (7.5), tourmaline (7.5), topaz (8), corundum (9), &c.,[11] caught between two differentially moving flint-surfaces in a landslip or a glacier;[12] and the increased force of impact in sand-blast due to the high specific gravity and greater size of these minerals may account for definite hair-like striations concomitant with polishing. 'Ice-action' has been too freely invoked in such cases. 'Satiny lustre' (due to hydration) is a different phenomenon from polishing.

B. The Genesis of Flint.

Assuming, as we may, the presence of dissolved alkaline silicates, furnished by the decomposition of felspars within the drainage-basin, in which spongoid and other low forms of life lived and died in the Cretaceous sea, it would appear that we may look for the supply of free silica in the genesis of flint to the reaction upon those silicates of organic acids, furnished in the decomposition of the dead sarcodic material, which (when living) formed the basis of the amœbiform constituents of the living sponges, &c., the siliceous spicules of sponges, Radiolaria, &c., being found often enclosed in the flint; and CO_2 (product of complete oxidation of organic matter) is known to readily displace SiO_2 from silicates of the alkalies in solution. Analyses of flints (Rammelsberg[13]) give various slight percentages of accessory potash, lime, water, and carbon, the last being probably the carbonised decomposition product of the postulated dead organic matter. The concretionary building-up of silica[14] in the form of flint nodules under the hydrostatic pressure of still water (often simulating in outline the form of the

[7] 'Organic Matter,' &c. (*supra cit.*).

[8] *Chem. and Phys. Studies*, &c.

[9] In the severe frost of January 1881.

[10] In an excavation on the upper flank of the Stort Valley (1912).

[11] Bristow, *Glossary of Mineralogy* (Longmans); Dick, *Nature*, vol. xxxvi. p. 91.

[12] *Nature*, September 26, 1912.

[13] *Mineralchemie* (II., pp. 163, 164).

[14] Cf. Kalkowsky, *Elemente der Lithologie*, p. 274—'Höchst wahrscheinlich ist die organische Herstammung für diese Kieselgesteine, a.s.w.'

original sponge) is readily understood; where, on the other hand, a slight lateral flow of the water occurred, a *tabular* form, with its slightly *laminated* structure (determining often the mode of fracture), would naturally occur. *Vertical walls* of flint in fissures in the extensively abraded Upper Chalk seem to tell of decomposition of the alkaline silicates during the deposition of 'the Lower London Tertiaries,' in which some of the liberated SiO_2 has often taken up Fe and K to form *glauconite*. In such cases decomposing Algæ, &c., may have furnished the acids required; or CO_2 furnished from the chalk itself might replace the SiO_2.

In areas where the alkaline silicates were wanting we should have the skeleton of the siliceous sponge preserved without any flinty investiture;[15] or even calcareous fossil sponges, as in the well-known 'Faringdon Sponge Beds.' *Silicification* of calcareous fossils, Foraminifera,[16] Echinoderms, &c., can be understood as a 'mass-reaction' of the alkaline silicates in the presence of a large excess of water, the alkaline base going for the CO_2 of the calcareous fossil, while the CaO became hydrated, leaving the SiO_2 to take the place of the original $CaCO_3$.

Thus:—

$$n\,H_2O + CaCO_3 + K_2SiO_3 = \underset{\text{(dissolved)}}{K_2CO_3} + \underset{\text{(dissolved)}}{Ca(OH)_2} + \underset{\text{(precipitated)}}{SiO_2} + (n-1)H_2O$$

(where n = an indefinitely large number);

or (in some cases?)

$$CaCO_3 + K_2SiO_3 = \underset{\text{(dissolved)}}{K_2CO_3} + \underset{\text{(Wollastonite)}}{CaSiO_3}.$$

The theory here propounded for the genesis of flint is the same as that suggested years ago to account for the formation of the 'woody opal' of the silicified trees of the lower Nile Valley, the sequence of chemical changes being similar in both cases (see paper by Capt. H. G. Lyons, R.E., F.R.S., in 'Q.J.G.S.,' Vol. l., November 1894, and the discussion thereon).

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6. *How the Relation between the Horizontal and Vertical Movement of the Water in Tides and Waves causes them to drive Sand forwards.* By VAUGHAN CORNISH, *D.Sc., F.R.G.S., F.G.S., F.C.S.*

The author dealt with the conditions of the transport of detritus superficially and in suspension. He pointed out that the *rate of subsidence* is the constant which best defines the behaviour of a granular material with respect to transportation by currents. He showed how detritus may be classified in three groups according to the value of this constant, these groups being familiar as shingle, sand, and mud, in the case of water-borne material, and gravel, sand, and dust in the case of wind-borne detritus.

It was pointed out that the change of direction of the vertical currents in sea-waves does not occur simultaneously with the change of direction of the horizontal currents, and it was shown that the result of the sequence of the changes is to endow waves with a shoreward action upon shingle and the coarser kinds of sand independently of any motion of translation in the water.

In tides also rise does not commence simultaneously with flow, nor fall with ebb, and the author showed that the sequence of these changes is such as to make the flood tide more effective than the ebb as an agent of littoral drift, apart from any greater speed of current.

Examples were given of the different positions in which deposits of detritus accumulate according to the rate of subsidence of the particles.

An explanation was given of the effect of a change in the inclination of current to the horizontal in sorting heterogeneous detritus, and examples were given for wind-borne material.

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[15] See Rupert Jones' edition of Dixon's *Geology of Sussex*.
[16] Sollas, *Age of the Earth*, chap. vi., pp. 150 ff., fig. 43.

7. *Interim Report on the Geology of Ramsay Island, Pembrokeshire.*

See Reports, p. 151.

8. *Report on the Old Red Sandstone Rocks of Kiltorcan, Ireland.*

See Reports, p. 152.

TUESDAY, SEPTEMBER 16.

The following Papers were read :—

1. *The Shelly and Graptolitic Faunas of the British Ordovician.* *By* Dr. Gertrude L. Elles.

There are two main types of 'shelly' faunas of Ordovician age in the British Isles, and each of these can be further subdivided into a number of sub-faunas which can be correlated by reference to associated graptolite-bearing beds.

Ordovician Faunas.

Graptolitic	Shelly	
Graptolite Zones	A	B
Zone of *Cephalog. acuminatus*	*Staurocephalus* fauna	*Staurocephalus* fauna
Zone of *Dicellog. anceps*		Exotic fauna . 4
Zone of *Dicellog. complanatus*	*Calymene planimarginata* fauna with sub-faunas (*a*) *Chasmops*; (*b*) *Asaphus Powisi*	Exotic fauna . 3
Zone of *Pleurog. linearis*		
Zone of *Dicranog. clingani*		
Zone of *Climacog. Wilsoni*		
	— — —?— — —	
Zone of *Climacog. peltifer*	*Ogygia Buchi* fauna, with *Asaphus tyrannus* sub-fauna	Exotic fauna . 2
Zone of *Nemag. gracilis*		
Zone of *Glyptog. teretiusculus*		Exotic fauna . 1
Zone of *Didymog. Murchisoni*	*Placoparia* fauna	
Zone of *Didymog. bifidus*		
Zone of *Didymog. hirundo*	*Ogygia Selwyni* fauna	
Zone of *Didymog. extensus*		
Zone of *Dichograptus*		

The main shelly types may be described as:

A. Asaphid-Trinucleid-Calymenid fauna.
B. Cheirurid-Lichad-Encrinurid fauna.

Evidence suggests that fauna B is an exotic fauna, possibly southern in origin, which migrated into the British area. Becoming early established in South Scotland, it soon spread west into Ireland, but did not dominate the whole British area till Ashgillian times.

2. *A First Revision of the British Ordovician Brachiopoda.* *By* CLARA E. SILVESTER, *M.Sc.*

The author gave a summary of the present stage of her researches among the British Ordovician brachiopoda, and presented a table of the known species, with their range and geological and geographical distribution. The species in each genus were grouped around well known forms selected as types.

3. *New Discoveries in the American Eocene.* *By* W. D. MATTHEW, *Ph.D.*

The American Museum of Natural History since 1903 has carried on systematic exploration of the Eocene formations of the West. Mr. Walter Granger, Associate Curator of Fossil Mammals, and his assistants have thoroughly explored the Bridger, Washakie, Wind River, and Big Horn Basins in Wyoming, and the San Juan Basin in New Mexico, the stratigraphy of each basin has been studied, and the exact level of every specimen recorded. By improved technique of collecting and preparation a great number of delicate and fragile specimens have been preserved, and the collections are more extensive than all those hitherto made, representing more than 4,000 catalogued individuals. The Eocene formations are not lake deposits (excepting the Green River and the Florissant) but have been deposited in flood plains and blocked river basins. The material is chiefly of volcanic origin, derived from the early Tertiary volcanoes of the Rocky Mountains, and distributed by streams, &c., and sometimes by the wind, in the mountain basins and on the plains. The ten successive faunæ now recognised are:

Upper Eocene	10. Upper Uinta	*Diplacodon* Zone.
	9. Upper Washakie	*Eobasileus* Zone.
Middle Eocene	8. Upper Bridger	*Uintatherium* Zone.
	7. Lower Bridger	*Orohippus* Zone.
Lower Eocene	6. Lost Cabin	*Lambdotherium* Zone.
	5. Lysite	
	4. Gray Bull	*Systemodon* Zone.
Paleocene	3. Clark's Fork	
	2. Torrejon	*Pantolambda* Zone.
	1. Puerco	*Polymastodon* Zone.

The Paleocene fauna does not contain the ancestors of the mid-Tertiary and later mammals; it is diminished in the Lower Eocene and dies out in the Lower Oligocene. The phyla which survived into the Oligocene or later Tertiary first appear in the Lower or Middle Eocene, for the most part suddenly, as if through immigration. The Clark's Fork fauna is in the uppermost levels of the Fort Union formation of the Big Horn Basin, Wyoming, and underlies the Lower Eocene ('Wasatch'). It contains none of the types which come in in the Lower Eocene (Perissodactyls, &c.), while its Paleocene types are in advanced stages.

Great progress has resulted in the study of the phylogeny and relationships of many groups, especially of the Creodonts, or primitive Carnivora, of the Fissipedia or modernised Carnivora, of the tenrecs, moles, hedgehogs, tree shrews, lemurs, of the horses, tapirs, titanotheres, rhinoceroses, chalicotheres, and of the early Artiodactyls, of the rodents, American Edentates, opossums, and other groups. The common ordinal characters of Placental Mammals are clearly defined in the Lower Eocene and the differentiation of the orders must have taken place during the Paleocene and late Cretaceous. The differentiation of the families of Placentals took place during the Eocene and later Tertiary. The modern genera date back to the Miocene or later.

The differentiation of Marsupials and Placentals must have occurred much earlier than the Tertiary, possibly during the Jurassic or early Cretaceous.

4. *Some further Notes on Palæoxyris and other allied Fossils, with Special Reference to some New Features found in Vetacapsula. By* L. Moysey, *M.B., B.C., F.G.S.*

Since the publication of a paper on Palæoxyris and other allied organisms in 1910 [1] so many fresh specimens have come to hand, and, as was only natural, several previously unrecorded examples have been described, notably some from the Lancashire coal measures by Mr. J. Wilfred Jackson,[2] that it seems desirable to record any new features that have been found in the new material, and also any new facts that may lead to the elucidation of the nature of these still very enigmatical organisms.

Taking in the first instance the genus Palæoxyris. The species *Palæoxyris helicteroides* (Morris) has been lately found in very large quantities in the Notts and Derbyshire coalfield. In this area they seem to be restricted to an horizon extending from the roof of the Top Hard coal downwards to above the Ell coal; a careful search in the measures below, wherever these are exposed, has not resulted in the discovery of any trace of this fossil. They were, some years ago,[3] discovered in great numbers in the open working of the Barnsley thick coal at Worsborough, near Barnsley, where some 300 odd specimens were collected by Mr. W. Gelder from a space six or seven yards in circumference, together with some specimens of *P. prendeli* (Lesq) and *P. carbonaria* (Schimper).

A hurried search in other claypits at horizons above and below this coal during the Sheffield Meeting of the British Association in 1910 produced enough specimens to make it probable that, if looked for, they may prove to be similarly quite common fossils in the great coalfield of which the Notts and Derbyshire area is merely an extension.

In fact, it seems probable that the habit of collectors to look for fossils only in the coal-measure shales, to the neglect of the ironstone nodules, may account for the paucity of specimens found in other coalfields.

The other species, *Palæoxyris carbonaria* (Schimper) and *Palæoxyris prendeli* (Lesq), seem, on the contrary, to be extremely rare in this area, and, when found, they are usually associated with quantities of *P. helicteroides*.

Vetacapsula cooperi (Machie and Crocker) [4] must still lay claim to being an extremely rare fossil. This genus is not restricted to a definite horizon in Derbyshire and Notts coalfields, but has been found to range from between the Waterloo and Ell coals at Newthorpe Claypit, downwards to the Kilburn coal at Loscoe Colliery. Three new specimens have been obtained—two from the silkstone coal, and one from the Kilburn coal. One of these, a specimen from the silkstone coal of the Calow Colliery, Chesterfield, shows a feature of great interest. When first found the fossil presented the appearance of a very much crushed example; but careful development revealed the fact that the fossil was, in reality, a perfectly normal flattened specimen, and the feature that gave rise to the apparent deformity was the presence of a medial, longitudinal flange, or fin-like structure, which extends along the 'median raphæ,' emphasised by the original describer of the genus, dismissed in my former paper as possibly due to crumpling, and again brought into prominence by Mr. J. Wilfred Jackson. It seems now that this 'median raphæ,' which appears to be a constant feature in every specimen recorded, may be caused in the ordinary specimens by this flange being torn off, and being left embedded in the matrix of the counterpart. It is also instructive to compare this new-found flange with that described by Mr. Bashford Dean on the egg-case of *Chimæra collei*.

From the examination of the four specimens in the author's collection and others elsewhere it is becoming more apparent that there are two distinct species included under the name of *Vetacapsula cooperi*. Owing, however, to the present uncertainty as to their affinities, and to the rarity of their occurrence, it seems best still to keep them under one trivial name, and separate them by

[1] L. Moysey, *Quart. Journ. Geol. Soc.*, vol. lxvi., 1910, pp. 329-345, and plates xxiv.-xxvii.

[2] J. Wilfred Jackson, *Lancashire Naturalist*, Jan. 1911.

[3] R. Kidston, *Naturalist*, 1897.

[4] E. J. Machie, *Geol. and Nat. Hist. Repertory*, vol. i. (1865 67), pp. 79-80.

applying the designation 'forma α' to those specimens in which the pedicle expands suddenly into the body, forming a distinct shoulder in the lower third of the body and giving rise to a 'deformity' or crumpling in that region; and the designation 'forma β' to those in which the pedicle expands more gradually into the body, giving to the specimen an ovate contour, with the 'deformity' or crumpling in the centre.

A curious and interesting feature is seen on the outer edge of all specimens conforming to 'forma β.' Just before the body contracts to form the beak there is found, by examination with the ordinary lens, a minute crenulation or crimping of the edge of the fossil, which may be compared with the markedly rugose lateral webs seen on the egg-cases of *Chimæra collei*, *Rhinochimæra*, and other chimæroids.

One fresh specimen of *Vetacapsula johnsoni* (Kidston) has come under notice from the Worsborough open works near Barnsley. It is in too crushed and imperfect condition to show any new features.

A new species of *Vetacapsula* has been recently described by Mr. Good,[5] from Pembrokeshire. It is very similar to *Vetacapsula johnsoni*, but is extremely small, measuring only five millimetres across, whereas *Vetacapsula johnsoni* measures twenty millimetres.

A new specimen of *Fayolia crenulata* (Moysey) has been discovered lately from a small heap of nodules still remaining from the Shipley claypit. The former example from Shipley consisted of the middle portion of the organism eleven centimetres long; another specimen, doubtfully referred to *Fayolia sterzliana* (Weiss), from the same locality, was evidently nearing its proximal or pedicular termination. The new specimen is of interest mainly because it shows the apex or distal termination, which appears to have been dome-shaped. The chief feature is the marked exaggeration of the crenulate 'collerette' which arises from the junction of the two spiral valves, and which forms a sort of spiral 'corona' round the apex of the fossil, strongly reminiscent of the corona at the summit of the egg-case of *Cestraceon philippi*.

5. *On the Occurrence of a Wind-Worn Rock Surface at Lilleshall Hill, Salop, and of Wind-Worn Stones there and elsewhere.* By FRANK RAW, *B.Sc., F.G.S.*

Lilleshall Hill, lying some five miles E.N.E. of Wellington, and extending N.E. and S.W., is a 'hogsback' of Uriconian, and is largely bare rock. The exposed rock of its S.E. side consists towards the N.E. of very hard hälleflintas, interstratified with somewhat softer tuff, and to the S.W. of this and opposite the Monument of still harder felsite conglomerate and grit.

Practically the whole of this rock surface has been ground smooth and, where hardest, has been highly polished, the smooth surface being traceable everywhere except where it has obviously been removed by weathering or quarrying. The surfaces of projecting masses of the conglomerate are perfectly fresh, being ground smooth, deeply fluted, and polished as by wind-blown sand, the radiating flutings showing the paths of escape of the prevalent wind. To the N.E. the rock surfaces have been much more even, perhaps based on a previously glaciated surface, and the flutings are parallel and in that direction less and less highly inclined, till at the N.E. end they lie at an inclination of 15° to 20° up to the North in North and South planes.

From the S.W. end of the wind-worn surfaces already described similar polishing can be traced across the hill to the N.W. on the steep rock surfaces of quartz-veined hälleflintas which bound on the S.W. the highest part of the hill.

South-west of this the crest of the hill is fairly flat and covered with grass. Here two reservoirs have been constructed for the Lilleshall water supply, and several of the stones thrown out were found to be beautifully wind-worn and polished. Two trial excavations made near by yielded a considerable proportion of wind-worn stones embedded in fine soft red sand.

[5] R. H. Good, *Quart. Journ. Geol. Soc.*, vol. lxix., 1913, p. 266, pl. xxx., fig. 3.

In one of the excavations carried to a depth of 29 inches there also occurred immediately beneath the turf a definite layer of white even-sized wind-worn sand, the grains measuring about $\frac{1}{30}$ inch in diameter, above the fine red sand with wind-worn stones.

The occurrence of wind-worn stones is also recorded from other localities in the Midlands, and specimens in illustration were exhibited.

WEDNESDAY, SEPTEMBER 17.

The following Papers and Reports were read:—

1. *On the Classification of Igneous Rocks.* *By* H. WARTH, *D.Sc.*

The classification I have suggested is based entirely on the chemical composition of the rocks in molecular proportions. On the strength of averages obtained from one thousand selected rocks sixfold repeated dichotomous division yielded sixty-four groups of intimately related rocks. By means of the factors obtained any other rock may be assigned to its respective group. A diagram demonstrates the relations of the groups to each other, and, moreover, a tetragonal projection shows the limits within which all possible combinations of acid and basic rock constituents are confined.

As similarly composed rocks generally form similar minerals, the majority of the rocks of each group are also mineralogically alike. It cannot be stated too strongly that the customary division of igneous rocks into acid, intermediate, basic, &c., is clearly also a chemical classification. The subsequent grouping into families and species is based upon mineralogical differences.

The method now proposed carries the classification on a chemical basis very much further, and accordingly brings the rocks in each of the sixty-four groups so much closer together.

Should it in time be found expedient to establish on similar principles a complete quantitative classification on exclusively mineralogical basis the two systems would most appropriately mutually supplement each other, notwithstanding a certain amount of overlapping.

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2. *On the Presence of Copper in the Sandstones of Exmouth.* *By* CECIL CARUS-WILSON, *F.R.S.E., F.G.S.*

The cliff section along the shore to the east of Exmouth golf links shows the red marls, with intercalated sandstones, and these were examined last winter to a point just beyond the High Lands of Orcombe. The sandstone was found to contain copper-carbonate. This is widely distributed, and shows itself as bright green patches upon the rock. Its presence is due to copper pyrites, which occurs as one of the mineral constituents of the sandstone, and which is undergoing decomposition. The sandstone is chiefly made up of rounded quartz and carnelian grains, bound together by a cement composed of the carbonates of lime and magnesia. There is also much manganese present. The grains of quartz give evidence of having been rounded by wind-action, and subsequently smoothed and polished by fine material suspended in water. They possess the conditions which, when accumulated on the beach, and sifted by wind and wave-action, are favourable to the production of musical sands, and several patches were found. Owing to the large percentage of lime and magnesia present in the springs issuing from the cliffs, and the precipitation of this on the evaporation of the water, much of the beach material footing the cliffs in places has been, and is now being, consolidated into masses of recent sandstone and conglomerate.

The presence of copper, carnelian, manganese, &c., indicates chemical and mineralogical conditions similar to those prevailing during the deposition of the German Rothliegendes.

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3. *On various Occurrences of Pillow Lavas in North and South Wales. By* A. Hubert Cox, *M.Sc., Ph.D., F.G.S., and* Professor O. T. Jones, *M.A., D.Sc., F.G.S.*

Pillow lavas were described from four localities, viz. :—

(*a*) Strumble Head, in Pembrokeshire.
(*b*) Cader Idris, in Merionethshire.
(*c*) Sarn Mellteyrn, near Pwllheli, Carnarvonshire.
(*d*) Careg, two miles N.N.W. of Aberdaron, Carnarvonshire.

(*a*) Strumble Head (A. H. C.).—References were made particularly to the work of Reed and Elsden. The rocks were formerly regarded as intrusive, and were described as of composite characters and possibly of later date than the main folding.

Variolitic rocks were described by Reed, who referred to the 'pillow structure' as 'spheroidal jointing.' The whole mass appears to consist largely of highly vesicular, basic flows, some with well-developed pillow structure, others showing transitions to non-pillowy types. Abundant chert occurs in association with the lavas, particularly those showing pronounced pillow structure. The most perfect pillows vary from a foot to eighteen inches in diameter, and consist of typical spilites, with thin, rod-like felspars of refractive index about 1·542, corresponding to oligoclase—the rocks are considerably decomposed, especially to calcite, chlorite, and epidote.

Among the above rocks are ophitic diabases, showing marked columnar jointing, which may in part represent sills.

(*b*) Cader Idris (A. H. C.).—A thick band of pillow lavas forms the highest point of the Cader Idris range, and thence strikes west-south-west. Its distribution was described in detail, and reference was made to the work of Ramsay and Geikie. A comparison of these rocks with those of Strumble Head discloses certain differences, especially in their uniformly less vesicular character and smaller amount of associated chert. Under the microscope the rock shows the character of a typical spilite; both rod- and lath-shaped felspars occur, the former being oligoclase, the latter somewhat richer in soda (refractive index below 1·541). The rock is considered to resemble most closely that of Mullion Island. In close association with it is the 'Eurite' (soda-granophyre) of Cole and Jennings. These lavas appear to occupy a stratigraphically higher horizon than the beds which yielded *Didymograptus bifidus* and *D. murchisoni* to Lake and Reynolds. The detailed examination of the area is still incomplete.

(*c*) Sarn Mellteyrn (O. T. J.).—References were made to the work of various authors, viz. : Ramsay, Harker, Raisin, Elsden, Matley.

The rocks are exposed by the roadside three-eighths of a mile south-west of Mellteyrn Church, where ten to twelve feet of typical pillow lavas overlain by a similar thickness mainly of non-pillowy rocks of allied characters are followed by flinty mudstones and micaceous shales. The spaces between the pillows are occupied by closely jointed dark-grey chert. The sediments dip to the east at a moderate angle, and probably pertain to the lower part of the Arenig. The pillow lava is finely vesicular and considerably decomposed; the felspar is oligoclase and forms lath-shaped microlites. From its structure and mineralogical character the rock is referred to the spilitic suite.

(*d*) Careg, near Aberdaron (O. T. J.).—These rocks have been described in detail by Raisin, and the pillow structure noted as 'spheroidal structure.' The present notes are intended to supplement that description in certain respects.

The pillow structure is seen near Careg quarries and near the coast; individual pillows have a length of about two feet, and are composed of a fine-grained rock with small vesicles. The felspars have the extinction-angle and refractive index of oligoclase-albite, and are highly charged with decomposition products. These rocks are undoubted spilites, and were claimed as such by Dewey and Flett; they are associated with 'limestones' of a peculiar character, together with beds and strings of jasper, which in places wraps round the pillows in the same manner as the chert near Sarn. The association of that rock with a pillow lava may perhaps be regarded as confirming Greenly's suggestion that the jaspers of Anglesey were originally cherts. The associated rocks at Careg have an extraordinarily complicated structure, and probably belong to the pre-Cambrian.

4. *Note on the Igneous Rocks of Ordovician Age.* *By* Arthur Hubert Cox, *M.Sc., Ph.D., F.G.S.*

The sedimentary rocks of Ordovician age consist principally of a great thickness of shales and mudstones, implying that the sediments were deposited over an area which, on the whole, was undergoing a slow but prolonged subsidence. Hence it is to be expected that the associated volcanic rocks should approximate to the keratophyre-spilite series.[1] This appears to be the case with the igneous rocks of most, if not all, the Ordovician areas.

Spilites themselves have now been recorded from the Ordovician of Ayrshire,[2] the Lleyn peninsula,[3] Merionethshire,[3] Pembrokeshire,[3] Cornwall,[4] and Co. Mayo.[5]

In a larger number of Ordovician volcanic areas typical spilites are absent, but in all cases the igneous rocks are found to bear close affinity to the rocks of the spilitic suite of Messrs. Dewey and Flett.[1]

These authors have pointed out that 'albitisation,' though not confined to igneous rocks of the suite, is especially met with among such rocks. Now the British Ordovician lavas are very commonly albitised, and often very completely so. Thus they nearly all approximate to the keratophyres; some of them—namely, the 'soda rhyolites'—being very acid, are quartz-keratophyres, according to Rosenbusch's nomenclature; others, the 'andesites,' of intermediate to almost basic character, are the keratophyres proper; while the 'acid andesites' and 'albite-trachytes'[6] would also be denoted as keratophyres on the Continent. In many areas every transition exists between the acid and intermediate rocks, while less commonly the more basic representatives of this series, the spilites proper, are to be found.

Although the Ordovician igneous rocks mostly have a high soda percentage, soda-amphiboles and soda-pyroxenes seem almost entirely absent. Riebeckite occurs in the Mynydd Mawr rock,[7] and perhaps in a few of the rhyolites,[8] while the peculiar pleochroism of certain hornblendes occurring as accessory constituents in some of the diabases probably points to the presence of soda in the molecule. There are, however, very few such cases recorded, considering the large number of rocks described, even if due allowance is made for many of the descriptions being by no means recent. Felspathoid minerals are also entirely absent from these Ordovician rocks.

This absence of felspathoid minerals and of soda-hornblendes and soda-augites constitutes an important difference between these rocks and those commonly described as alkaline or Atlantic in type. It may be noted that Rosenbusch[9] first placed the keratophyres among his alkaline division, but later, taking into consideration the associated types, classed them with the calcalkaline rocks.

A point worth notice in the Ordovician igneous rock is the frequent presence of a rhombic pyroxene. Rosenbusch has pointed out that, whereas in calc-alkaline (Pacific) rocks olivine makes its appearance at an early stage as the rocks become basic, in the alkaline (Atlantic) rocks there is a marked tendency for the *rôle* of olivine to be taken by hornblende and biotite, even in some cases where the magma was ultrabasic.

In the keratophyres rhombic pyroxenes are of very common occurrence, and

[1] H. Dewey and J. S. Flett, *Geol. Mag.*, 1911, p. 202.

[2] *The Silurian Rocks of Britain,* vol. i., Scotland, *Mem. Geol. Surv.*, 1899, p. 85.

[3] A. H. Cox and O. T. Jones, this report.

[4] H. Fox and J. J. H. Teall, *Quart. Journ. Geol. Soc.*, vol. 49 (1893), p. 85; and *Mem. Geol. Surv.*, 'The Geology of the Lizard,' 1912, p. 165.

[5] C. J. Gardiner and S. H. Reynolds, *Quart. Journ. Geol. Soc.*, vol. 65 (1909), p. 136; and vol. 68 (1912), p. 75.

[6] H. H. Thomas, *Quart. Journ. Geol. Soc.*, vol. 67 (1911), p. 193.

[7] A. Harker, *Bala Volcanic Series*, 1889, p. 50.

[8] W. G. Fearnsides, *Proc. Geol. Assoc.*, vol. 22 (1912), p. 206.

[9] *Mikroskopische Physiographie der Massigen Gesteine*, vol. 2, pt. 2 (1908), p. 1493.

are sometimes the only dark minerals present. In the spilites and many related basalts a mineral of closely related composition, 'magnesium-diopoide,' plays an important part. The same mineral, also described as 'enstatite-augite,'[10] 'sahlite,' &c., and often regarded as an intergrowth of rhombic and monoclinic pyroxenes,[11] is very common among the diabases found in association with spilites and keratophyres, and the diabases may often be quite basic without containing any olivine.[12]

Thus in rocks of this suite rhombic pyroxenes (in some cases intergrown with monoclinic pyroxenes) would appear to take in some degree the place of olivine in the corresponding Pacific rocks, and of hornblende (and biotite) in corresponding Atlantic types.

A striking feature in the various volcanic series of Ordovician age is the importance of the pyroclastic rocks. It is not uncommon to find tuffs of various kinds build up the whole, or nearly so, of a thick volcanic series. This is in marked contrast to all the volcanic series of later date in the British area, and is not entirely explained by the fact that the eruptions were submarine, and that therefore the elastic products were more likely to be preserved. The further explanation is probably to be looked for in the viscosity of the magmas. This high viscosity has been noted in the spilites and some other rocks,[13] and is apparent from the field relations in most cases. It is just such highly viscous lavas that one would expect to furnish a large amount of pyroclastic material.[14] In this connection it may be pointed out that, whereas the more basic rocks of the keratophyre-spilite series are almost invariably highly vesicular, the acid and acid-intermediate members of the series (quartz keratophyres, &c.) are as frequently non-vesicular.

It has been shown by Messrs. Dewey and Flett[15] that rocks of the spilitic suite are found in areas which have undergone a slow but prolonged subsidence; hence such rocks will be typically produced in areas in which a geosyncline is in process of formation. Now from the theory of isostasy we may expect such areas to be soon affected by a movement of compression resulting in mountain-building, with accompanying folding, cleavage, and thrusting. This type of movement will very likely be closely associated with the production of rocks of a calcalkaline (Pacific) type.

In short, areas in which spilitic rocks are found will usually be strongly affected by cleavage, and will often be complicated by the occurrence of igneous rocks of a later and (apparently) quite different cycle.

In Britain good examples of this sequence of events are seen in the relation of (i.) the post-Silurian calcalkaline igneous rocks of Scotland and Ireland to the spilitic lavas of Ordovician[16] age, and (ii.) the igneous rocks connected with the uprise of the Armorican chain to the spilitic rocks of Middle and Upper Devonian age in Devon and Cornwall. The occurrence of spilitic rocks in areas which have been subjected to overfolding was noted by Steinman.[17]

The Ordovician igneous rocks would appear to afford a favourable ground for ascertaining whether the connection between rock-types and types of earth-movement holds good to a greater extent than has been hitherto suggested. The great succession of Ordovician shales and mudstones is locally interrupted by coarser deposits, or even by small unconformities implying a certain amount of uplift, or, at any rate, a checking in the rate of subsidence. Further, the subsidence continued in certain areas into Silurian time, while in other localities there is a more or less strong unconformity between the two systems.

[10] Wahl, Tscherm, *Min. und Petr. Mitth.* n. s., vol. 26 (1907), pp. 21 and 26.

[11] J. V. Elsden, *Quart. Journ. Geol. Soc.*, vol. 64 (1908), p. 287, with references.

[12] Harker, *Bala Volcanic Series* (1889), p. 77.

[13] H. H. Thomas, *Quart. Journ. Geol. Soc.*, vol. 64 (1911), p. 195.

[14] See Dakyns and Greenly, 'The Felsitic Slates of Snowdon,' *Geol. Mag.*, 1905, p. 541.

[15] *Op. supra cit.*

[16] The few examples of contemporaneous igneous rocks in the Silurian appear to be keratophyres and spilites (excluding the Downtonian lavas of Kincardineshire).

[17] *Ber. Nat. Gesell.* Freiburg i. B., 16 (1905), p. 44.

In view of these facts, we may perhaps expect that further research will show some constant difference between the facies of the igneous rocks in areas where subsidence was continuous and the facies in areas where subsidence was interrupted by uplift. The greater the extent of the uplift the more clearly may it be expected to express itself in the composition of the contemporaneous igneous rocks; so that in areas where phases of uplift played an important part the rocks may be expected to belong to types transitional between typical spilitic and typical calcalkaline rocks.

5. *Recent Discoveries in the Stockingford Shales near Nuneaton.* *By* V. C. Illing, *B.A., F.G.S.*

During recent mapping of the sub-divisions of the Stockingford shales between Nuneaton and Merevale, fossils have been found at various horizons which indicate that the Cambrian succession in this area is almost, if not quite, complete.

Among these fossil-bearing horizons are the following:—

1. *Lower Purley Shales.*—Shales from a surface working 200 yards south of Worthington Farm, near Hartshill, contain fragments of *Olenellus.* The fossiliferous beds are forty feet above the base of Purley shales.

Mr. Pringle, of the Geological Survey, has found *Olenellus* in nodules at the base of the Purley shales in Jee's Sett Quarry (Summary of Progress, 1913).

2. *Lower Oldbury Shales.*—(*a*) Excavations in Hartshill Hayes have proved that the basal ninety feet of the Oldbury shales are of Menevian age. They contain the zones of *Paradoxides Davidis* and *P. Hicksii* in their upper and middle beds, while the lower beds contain *Agnostus atavus,* and correspond with Tullberg's *Ag. atavus* zone, and with part at least of the Lower Menevian of Sweden. The *Trilobite* fauna includes the genera *Paradoxides, Anopolenus, Conocoryphe, Holocephalina, Liostracus, Microdiscus,* and *Agnostus,* no less than fifteen species of the last genus having been found. At the top of the series there occurs a calcareous conglomerate, containing fragments of the underlying type of shale and indicating a probable unconformity.

(*b*) In a new cutting near Oldbury Reservoir *Olenus truncatus* and *Ag. pisiformis* var. *obesus* occur, proving that these beds are of Upper Maentwrog age.

Between the Maentwrog and Dolgelly horizons a series of curly bedded flagstones have been detected. These are very similar to the Ffestiniog flags, and their position would seem to indicate that they are of Ffestiniog age. The beds are badly exposed and have yielded no fossils up to the present.

Thus the Oldbury shales represent a large proportion of the Cambrian succession, and in view of this fact, and also of their extreme thickness (2,000 feet), I propose a further sub-division of this group, the classification of the whole succession being as follows:—

Merevale Shales		Lower Tremadoc.
Oldbury Shales	4. Monks Park Shales	Dolgelly.
	3. Moor Wood Flags and Shales	Ffestiniog.
	2. Outwoods Shales	Maentwrog.
	1. Abbey Shales	Menevian.
Purley Shales	Upper	Menevian ?
	Mid	
	Lower	Taconian.
Hartshill Quartzite	Camp Hill Grit	
	Tuttle Hill Quartzite	
	Park Hill Quartzite	

6. *Notes on certain Trilobites found in the Stockingford Shales.* *By* V. C. Illing, *B.A.*, *F.G.S.*

Among the fossils found at Hartshill Hayes in the Abbey shale sub-division of the Stockingford shales, numerous forms occur, representing young stages in the development of certain *Trilobite* genera. Among these are the following:

1. *Liostracus* sp.—The development is similar to that of *Liostracus* as described by G. F. Matthew.

2. *Holocephalina* sp.—The early stages of this genus possess a well-marked glabella, widening anteriorly. This becomes less convex in later stages, its anterior margin disappears, and finally the glabella is only represented by two short posterior grooves.

3. *Paradoxides Hicksii.*—The development is similar to that of *Paradoxides* as described by G. F. Matthew.

4. Certain new forms of *Agnostus.*—The anterior portion of the glabella becomes obliterated in the later stages, while the axis of the tail becomes relatively larger with increased development.

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7. *The Carboniferous Limestone at the Head of the Vale of Neath, South Wales.* *By* C. H. Cunnington.

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8. *On a New Form of Rock-cutting Machine.* *By* Professor W. S. Boulton, *D.Sc.*

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9. *Interim Report of the Geological Photographs Committee.*

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10. *Interim Report on the Microscopical and Chemical Composition of the Charnwood Rocks.*

SECTION D.—ZOOLOGY.

PRESIDENT OF THE SECTION.—H. F. GADOW, M.A., Ph.D., F.R.S.

THURSDAY, SEPTEMBER 11.

The President delivered the following Address:—

'ADDRESS your audience about what you yourself happen to be most interested in, speak from the fullness of your heart and make a clean breast of your troubles.' That seemed good advice, and I shall endeavour to follow it, taking for my text old and new aims and methods of morphology, with special reference to resemblances in function and structure on the part of organs and their owners in the animal kingdom. First, however, allow me to tell you what has brought me to such a well-worn theme. Amongst the many impressions which it has been my good luck to gather during my travels in that enchanting country Mexico are the two following:—

First, the poisonous Coral snakes, *Elaps*, in their beautiful black, red, and yellow garb; it varies in detail in the various species of *Elaps*, and this garb, with most of the variations too, occurs also in an astonishing number of genera and families of semi-poisonous and quite harmless Mexican snakes, some of which inhabit the same districts. A somewhat exhaustive study of these beauties has shown incontestably that these often astoundingly close resemblances are not cases of mimicry, but due to some other co-operations.

Secondly, in the wilds of the State of Michoacan, at two places, about 20 and 70 miles from the Pacific Coast, I myself collected specimens of *Typhlops* which Dr. Boulenger without hesitation has determined as *Typhlops braminus*. Now, whilst this genus of wormlike, blind little snakes has a wide circumtropical distribution, *T. braminus* had hitherto been known only from the islands and countries of the Indian Ocean basin, never from America, nor from any of the Pacific Islands which possess other kinds of *Typhlops*. Accidental introduction is out of the question. Although the genus is, to judge from its characters, an especially old one, we cannot possibly assume that the species *braminus*, if the little thing had made its way from Asia to Mexico by a natural mode of spreading, has remained unaltered even to the slightest detail since that geological epoch during which such a journey could have taken place. There remains the assumption that amongst the of course countless generations of *Typhlops* in Mexico some have hit off exactly the same kind of permutation and combination of those characters which we have hitherto considered as specific of *braminus*, just as a pack of cards may in a long series of deals be dealt out more than once in the same sequence.

The two cases are impressive. They reminded me vividly that many examples of very discontinuous distribution—which anyone who has worked at zoogeography will call to mind—are exhibited by genera, families, and even orders, without our knowing whether the groups in which we class them are natural or artificial. The ultimate appeal lies with anatomy.

Introduced to Zoology when Haeckel and Gegenbaur were both at their zenith, I have been long enough a worker and teacher to feel elated by its progress and depressed by its shortcomings and failures. Perhaps we have gone too fast, carried along by methods which have yielded so much and therefore have made us expect too much from them.

Gegenbaur founded the modern comparative anatomy by basing it upon the theory of descent. The leading idea in all his great works is to show that Transformation, 'continuous adjustment' (Spencer), has taken place; he stated the problem of comparative anatomy as the reduction of the differences in the organisation of the various animals to a common condition; and as homologous organs he defined those which are of such a common, single origin. His first work in this new line is his classical treatise on the Carpus and Tarsus (1864).

It followed from this point of view that the degree of resemblance in structure between homologous organs and the number of such kindred organs present is a measure for the affinity of their owners. So was ushered in the era of pedigrees of organs, of functions, of the animals themselves. The tracing of the divergence of homogenous parts became all-important, whilst those organs or features which revealed themselves as of different origin, and therefore as analogous only, were discarded as misleading in the all-important search for pedigrees. Functional correspondence was dismissed as 'mere analogy,' and even the systematist has learnt to scorn these so-called physiological or adaptive characters as good enough only for artificial keys. A curious view of things, just as if it was not one and the same process which has produced and abolished both sets of characters, the so-called fundamental or 'reliable' as well as the analogous.

As A Willey has put it happily, there was more rejoicing over the discovery of the homology of some unimportant little organ than over the finding of the most appalling unrelated resemblance. Morphology had become somewhat intolerant in the application of its canons, especially since it was aided by the phenomenal growth of Embryology. You must not compare ectodermal with endodermal products. You must not make a likeness out of another germinal layer or anything that appertains to it, because if you do that would be a horror, a heresy, a homoplasy.

Haeckel went so far as to distinguish between a true Homology, or Homophyly, which depends upon the same origin, and a false Homology, which applies to all those organic resemblances which derive from an equivalent adaptation to similar developmental conditions. And he stated that the whole art of the morphologist consists in the successful distinction between these two categories. If we were able to draw this distinction in every case, possibly some day the grand tree of each great phylum, maybe of the whole kingdom, might be reconstructed. That would indeed be a tree of knowledge, and, paradoxically enough, it would be the deathblow to classification, since in this, the one and only true natural system, every degree of consanguinity and relationship throughout all animated nature, past and present, would be accounted for; and to that system no classification would be applicable, since each horizon would require its own grouping. There could be definable neither classes, orders, families, nor species, since each of these conceptions would be boundless in an upward or downward direction.

Never mind the ensuing chaos; we should at least have the pedigree of all our fellow creatures, and of ourselves among them. Not absolute proof, but the nearest possible demonstration that transformation has taken place. Empirically we know this already, since, wherever sufficient material has been studied, be it organs, species or larger groups, we find first that these units had ancestors and secondly that the ancestors were at least a little different. Evolution is a fact of experience proved by circumstantial evidence. Nevertheless we are not satisfied with the conviction that life is subject to an unceasing change, not even with the knowledge of the particular adjustments. We now want to understand the motive cause. First What, then How, and now Why?

It is the active search for an answer to this question (Why?) which is characteristic of our time. More and more the organisms and their organs are considered as living, functional things. The mainspring of our science, perhaps of all science, is not its utility, not the desire to do good, but, as an eminently matter-of-fact man, the father of Frederick the Great, told his Royal Acade-

micians (who, of course, were asking for monetary help) in the following shockingly homely words: 'Der Grund ist derer Leute ihre verfluchte Curieusität.' This blamed curiosity, the beginnings of which can be traced very far back in the lower animals, is most acutely centred in our desire to find out who we are, whence we have come, and whither we shall go. And even if Zoology, considering the first and last of these three questions as settled, should some day solve the problem: Whence have we come? there would remain outside Zoology the greater Why?

Generalisations, conclusions, can be arrived at only through comparison. Comparison leads no further where the objects are alike. If, for instance, we restrict ourselves to the search for true homologies, dealing with homogenes only, all we find is that once upon a time some organism has produced, invented, a certain arrangement of *Anlage* out of which that organ arose, the various features of which we have compared in the descendants. Result: we have arrived at an accomplished fact. These things, in spite of all their variety in structure and function, being homogenes, tell us nothing, because according to our mode of procedure we cannot compare that monophyletic *Anlage* with anything else, since we have reduced all the homogenous modifications to one. Logically it is true that there can have been only one, but in the living world of nature there are no such ironbound categories and absolute distinctions. For instance, if we compare the organs of one and the same individual, we at once observe repetition, *e.g.*, that of serial homology, which implies many difficulties, with very different interpretations. Even in such an apparently simple case as the relation between shoulder girdle and pelvis we are at a loss, since the decision depends upon our view as to the origin of the paired limbs, whether both are modified visceral arches, and in this case serially repeated homogenes, or whether they are the derivatives from one lateral fin, which is itself a serial compound, from which, however, the proximal elements, the girdles, are supposed to have arisen independently. What is metamerism? Is it the outcome of a process of successive repetitions so that the units are homogenes, or did the division take place at one time all along the line, or is it due to a combination of the two procedures?

The same vagueness finds its parallel when dealing with the corresponding organs of different animals, since these afford the absolute chance that organs of the same structure and function may not be reducible to one germ, but may be shown to have arisen independently in time as well as with reference to the space they occupy in their owners. As heterogenes they can be compared as to their causes. In the study of the evolution of homogenes the problem is to account for their divergencies, whilst the likeness, the agreements, so to speak their greatest common measure, is *eo ipso* taken to be due to inheritance. When, on the contrary, dealing with heterogenes we are attracted by their resemblances, which since they cannot be due to inheritance must have a common cause outside themselves. Now, since a leading feature of the evolution of homogenes is divergence, whilst that of heterogenes implies convergence from different starting-points, it follows that the more distant are these respective starting-points (either in time or in the material) the better is our chance of extracting the greatest common measure out of the unknown number of causes which combine in the production of even the apparently simplest organ.

These resemblances are a very promising field and the balance of importance will more and more incline towards the investigation of Function, a study which, however, does not mean mere physiology with its present-day aims in the now tacitly accepted sense, but that broad study of life and death which is to yield the answer to the question Why?

Meantime, comparative anatomy will not be shelved; it will always retain the casting-vote as to the degree of affinity among resemblances, but emphatically its whole work is not to be restricted to this occupation. It will increasingly have to reckon with the functions, indeed never without them. The animal refuses to yield its secrets unless it be considered as a living individual. It is true that Gegenbaur himself was most emphatic in asserting that an organ is the result of its function. Often he held up to scorn the embryographer's method of muddling cause and effect, or he mercilessly showed that in the reconstruction of the evolution of an organ certain features cannot have been phases unless they imply physiological continuity. And yet how moderately is function dealt

with in his monumental text-book and how little is there in others, even in text-books of Zoology!

Habt alle die Theile in der Hand,
Fehlt leider nur das geistige Band—Life!

We have become accustomed to the fact that like begets like with small differences, and from the accepted standpoint of evolution versus creation we no longer wonder that descendants slowly change and diverge. But we are rightly impressed when unlike comes to produce like, since this phenomenon seems to indicate a tendency, a set purpose, a *beau idéal*, which line of thought or rather imperfect way of expression leads dangerously near to the crassest teleology.

But, teleology apart, we can postulate a perfect agreement in function and structure between creatures which have no community of descent. The notion that such agreement *must* be due to blood-relationship involved, among other difficulties, the dangerous conclusion that the hypothetical ancestor of a given genuine group possessed in potentiality the *Anlagen* of all the characters exhibited by one or other of the component members of the said group.

The same line of thought explained the majority of human abnormalities as atavistic, a procedure which would turn the revered ancestor of our species into a perfect museum of antiquities, stocked with tools for every possible emergency.

The more elaborate certain resemblances are the more they seem to bear the hall-mark of near affinity of their owners. When occurring in far-related groups they are taken at least as indications of the homology of the organs. There is, for instance, a remarkable resemblance between the *bulla* of the whale's ear and that of the Pythonomorph *Plioplatycarpus*. If you homologise the mammalian tympanic with the quadrate the resemblance loses much of its perplexity, and certain Chelonians make it easier to understand how the modification may have been brought about. But, although we can arrange the Chelonian, Pythonomorph, and Cetacean conditions in a progressive line, this need not represent the pedigree of this *bulla*. Nor is it necessarily referable to the same *Anlage*. Lastly if, as many anatomists believe, the reptilian quadrate appears in the mammals as the *incus*, then all homology and homogeny of these *bullæ* is excluded. In either case we stand before the problem of the formation of a *bulla* as such. The significant point is this, that although we dismiss the *bulla* of whale and reptile as obvious homoplasy, such resemblances, if they occur in two orders of reptiles, we take as indicative of relationship until positive evidence to the contrary is produced. That this is an unsound method is brought home to us by an ever-increasing number of cases which tend to throw suspicion on many of our reconstructions. Not a few zoologists look upon such cases as a nuisance and the underlying principle as a bugbear. So far from that being the case such study promises much beyond the pruning of our standard trees—by relieving them of what reveal themselves as grafts instead of genuine growth—namely, the revelation of one or other of the many agencies in their growth and structure.

Since there are all sorts and conditions of resemblances we require technical terms. Of these there is abundance, and it is with reluctance that I propose adding to them. I do so because unfortunately some terms are undefined, perhaps not definable; others have not 'caught on,' or they suffer from that mischievous law of priority in nomenclature.

The terms concerning morphological homologies date from Owen; Gegenbaur and Haeckel re-arranged them slightly. Lankester, in 1870, introduced the terms homogenous, meaning alike born, and homoplastic or alike moulded. Mivart rightly found fault with the detailed definition and the subdivisions of Homoplasy, and very logically invented dozens of new terms, few of which, if any, have survived. It is not necessary to survey the ensuing literature. For expressing the same phenomenon we have now the choice between Homoplasy, Homomorphy, Isomorphy, Heterophyletic convergence, Parallelism, &c. After various papers by Osborn, who has gone very fully into these questions, and Willey's 'Parallelism,' Abel, in his fascinating 'Grundzüge der Palaeobiologie,' has striven to show by numerous examples that the resemblances or 'adaptive formations' are cases of parallelism if they depend upon the same function of homologous organs, and convergences if brought about by the same function of non-homologous organs.

I suggest an elastic terminology for the various resemblances indicative of the degree of homology of the respective organs, the degree of affinity of their owners, and lastly the degree of the structural likeness attained.

Homogeny.—The structural feature is invented once and is transmitted, without a break, to the descendants, in which it remains unaltered, or it changes by mutation or by divergence, neither of which changes can bring the ultimate results nearer to each other. Nor can their owners become more like each other, since the respective character made its first appearance either in one individual, or, more probably, in many of one and the same homogenous community.

Homoplasy.—The feature or character is invented more than once, and independently. This phenomenon excludes absolute identity; it implies some unlikeness due to some difference in the material, and there is further the chance of the two or more inventions, and therefore also of their owners, becoming more like each other than they were before.

Categories of Homoplasy.

Isotely.—If the character, feature, or organ has been evolved out of homologous parts or material, as is most likely the case in closely related groups, and if the subsequent modifications proceed by similar stages and means, there is a fair probability or chance of very close resemblance. *Iso-tely* : the same mark has been hit.

Homœotely.—Although the feature has been evolved from homologous parts or material, the subsequent modifications may proceed by different stages and means, and the ultimate resemblance will be less close, and deficient in detail. Such cases are most likely to happen between groups of less close affinity, whether separated by distance or by time. *Homœo-tely* : the same end has been fairly well attained. The target has been hit, but not the mark.

Parat.ely.—The feature has been evolved from parts and material so different that there is scarcely any or no relationship. The resulting resemblance will at best be more or less superficial; sometimes a sham, although appealing to our fancy. *Para-tely* : the neighbouring target has been hit.

Examples.

Isotely : Bill of the *Ardeidæ Balæniceps* (Africa) and *Cancroma* (Tropical America).

Zygodactyle foot of *Cuckoos, Parrots, Woodpeckers* $\left(\frac{2\cdot3}{1\cdot4}\right)$.

Patterns and coloration of *Elaps* and other snakes.

Parachute of *Petaurus* (marsupial); *Pteromys* (rodent) and *Galeopithecus*.

Perissodactylism of *Litopterna* and Hippoids.

Bulla auris of *Plioplatycarpus* (Pythonomorph) and certain Whales; if tympanic = quadrate.

Grasping instruments or nippers in Arthropods: pedipalps of *Phryne*; chelæ of Squill; first pair of Mantis' legs.

General appearance of Moles and *Notoryctes*, if both considered as mammals; of Gulls and Petrels, if considered as birds.

Homœotely : Heterodactyle foot of Trogons $\left(\frac{3\cdot4}{2\cdot1}\right)$.

Jumping foot of *Macropus, Dipus, Tarsius*.

Intertarsal and cruro-tarsal joint.

Fusion and elongation of the three middle metarsals of *Dipus* and *Rhea*.

Paddles of Ichthyosaurs. Turtles, Whales, Penguins.

'Wings' of Pterosaurs and Bats.

Long flexible bill of *Apteryx* and Snipes.

Proteroglyph dentition of Cobras and Solenoglyph dentition of Vipers.

Loss of the shell of *Limax* and *Aplysia*.

Complex molar pattern of Horse and Cow.

Parately : Bivalve shell of Brachiopods and Lamellibranchs.

Stretcher-sesamoid bone of Pterodactyls (radial carpal); of Flying Squirrels (on pisiform); of *Anomalurus* (on olecranon).

Bulla auris of Pythonomorph (quadrate) and Whale (tympanic); is *incus* = quadrate.

'Wings' of Pterosaurs, or Bats, and Birds.

The distinction between these three categories must be vague because that between homology and analogy is also arbitrary, depending upon the standpoint of comparison. As lateral outgrowths of vertebræ all ribs are homogenes, but if there are at least hæmal and pleural ribs then those organs are not homologous even within the class of fishes. If we trace a common origin far enough back we arrive near bedrock with the germinal layers. So there are specific, generic, ordinal, &c., homoplasies. The potentiality of resemblance increases with the kinship of the material.

Bateson, in his study of Homœosis, has rightly made the solemn quotation: 'There is the flesh of fishes . . . birds . . . beasts, &c.' Their flesh will not and cannot react in exactly the same way under otherwise precisely the same conditions, since each kind of flesh is already biased, encumbered by inheritances. If a certain resemblance between a reptile and mammal dates from Permian times, it may be homogenous, like the pentadactyle limb which as such has persisted; but if that resemblance has first appeared in the Cretaceous period it is Homoplastic, because it was brought about long after the class division. To cases within the same order we give the benefit of the doubt more readily than if the resemblance concerned members of two orders, and between the phyla we rightly seek no connection. However, so strongly is our mode of thinking influenced by the principle of descent that, if the same feature happen to crop up in more than two orders, we are biased against Homoplasy.

The readiness with which certain Homoplasies appear in related groups seems to be responsible for the confounding of the potentiality of convergent adaptation with a latent disposition, as if such cases of Homoplasy were a kind of temporarily deferred repetition, *i.e.*, after all due to inheritance. This view instances certain recurring tooth patterns, which, developing in the embryonic teeth, are said not to be due to active adaptation or acquisition but to selection of accomplished variations, because it is held inconceivable that use, food, &c., should act upon a finished tooth. It is not so very difficult to approach the solution of this apparently contradictory problem. Teeth, like feathers, can be influenced long before they are ready by the life experiences of their predecessors. A very potent factor in the evolution of Homoplasies is correlation, which is sympathy, just as inheritance is reminiscence. The introduction of a single new feature may affect the whole organism profoundly, and one serious case of Isotely may arouse unsuspected correlations and thus bring ever so many more homoplasies in its wake.

Function is always present in living matter; it is life. It is function which not only shapes, but creates the organ or suppresses it, being indeed at bottom a kind of reaction upon some stimulus, which stimuli are ultimately all fundamental, elementary forces, therefore few in number. That is a reason why Nature seems to have but few resources for meeting given 'requirements'—to use an everyday expression which really puts the cart before the horse. This paucity of resources shows itself in the repetition of the same organs in the most different phyla. The eye has been invented dozens of times. Light, a part of the environment, has been the first stimulus. The principle remains the same in the various eyes; where light found a suitably reacting material a particular evolution was set going, often round about, or topsy-turvy, implying amendments; still, the result was an eye. In advanced cases a scientifically constructed dark chamber with lens, screen, shutters, and other adjustments. The detail may be unimportant, since in the various eyes different contrivances are resorted to.

Provided the material is suitable, plastic, amenable to prevailing environmental or constitutional forces, it makes no difference what part of an organism is utilised to supply the requirements of function. You cannot make a silk purse out of a sow's ear, but you can make a purse, and that is the important point. The first and most obvious cause is function, which itself may arise as an incidental action due to the nature of the material. The oxydising of the blood is such a case, and respiratory organs have been made out of whatever parts invite osmotic contact of the blood with air or water. It does not matter whether respiration is carried on by ecto- or by endodermal epithelium. Thus are developed internal gills, or lungs, both of which may be considered as referable to pharyngeal pouches; but where the outer skin has become suitably

osmotic, as in the naked Amphibia, it may evolve external gills. Nay, the whole surface of the body may become so osmotic that both lungs and gills are suppressed, and the creature breathes in a most pseudo-primitive fashion. This arrangement, more or less advanced, occurs in many Urodeles, both American and European, belonging to several sub-families, but not in every species of the various genera. It is therefore a case of apparently recent Isotely.

There is no prejudice in the making of a new organ except in so far that every organism is conservative, clinging to what it or its ancestors have learnt or acquired, which it therefore seeks to recapitulate. Thus in the vertebrata the customary place for respiratory organs is the pharyngeal region. Every organism, of course, has an enormous back history; it may have had to use every part in every conceivable way, and it may thereby have been trained to such an extent as to yield almost at once, like a bridle-wise horse to some new stimulus, and thus initiate an organ straight to the point.

Considering that organs put to the same use are so very often the result of analogous adaptation, homoplasts with or without affinity of descent, are we not justified in accusing morphology of having made rather too much of the organs as units, as if they were concrete instead of inducted abstract notions? An organ which changes its function may become a unit so different as to require a new definition. And two originally different organs may come to resemble each other so much in function and structure that they acquire the same definition as one new unit. To avoid this dilemma the morphologist has, of course, introduced the differential of descent, whether homologous or analogous, into his diagnoses of organs.

The same principles must apply to the classification of the animals. To group the various representative owners of cases of isotely together under one name, simply because they have lost those characters which distinguished their ancestors, would be subversive of phyletic research. It is of the utmost significance that such 'convergences' (rather 'mergers,' to use an administrative term) do take place, but that is another question. If it could be shown that elephants in a restricted sense have been evolved independently from two stems of family rank, the convergent terminals must not be named *Elephantinæ*, nor can the representatives of successive stages or horizons of a monophyletic family be designated and lumped together as subfamilies. And yet something like this practice has been adopted from Cope by experienced zoologists with a complete disregard of history, which is an inalienable and important element in our science.

This procedure is no sounder than would be the sorting of our Cartwrights, Smiths, and Bakers of sorts into as many natural families. It would be subversive of classification, the aim of which is the sorting of a chaos into order. We must not upset the well-defined relative meaning of the classificatory terms which have become well-established conceptions; but what such an assembly as the terminal elephants should be called is a new question, the urgency of which will soon become acute. It applies at least to assemblies of specific, generic, and family rank, for each of which grades a new term, implying the principle of convergence, will have to be invented. In some cases geographical terms may be an additional criterion. Such terms will be not only most convenient, but they will at once act as a warning not to use the component species for certain purposes. There is, for instance, the case of *Typhlops braminus*, mentioned at the beginning of this address. Another case is the dog species, called *Canis familiaris*, about which it is now the opinion of the best authorities that the American dogs of sorts are the descendants of the Coyote, while some Indian dogs are descendants of a jackal, and others again are traceable to some wolf. The 'dog,' a definable conception, has been invented many times, and in different countries and out of different material. It is an association of converged heterogeneous units. We have but a smile for those who class whales with fishes, or the blind-worm with the snakes; not to confound the Amphibian Cœcilians with Reptilian *Amphisbœnas* requires some training; but what are we to do with creatures who have lost or assimilated all those differential characters which we have got used to rely upon?

In a homogeneous crowd of people we are attracted by their little differences, taking their really important agreements for granted; in a compound crowd we

at once sort the people according to their really unimportant resemblances. That is human nature.

The terms 'convergence' and 'parallelism' are convenient if taken with a generous pinch of salt. Some authors hold that these terms are but imperfect similes, because two originally different organs can never converge into one identical point, still less can their owners whose acquired resemblance depresses the balance of all their other characters. For instance, no lizard can become a snake, in spite of ever so many additional snake-like acquisitions, each of which finds a parallel, an analogy in the snakes. Some zoologists therefore prefer contrasting only parallelism and divergence. A few examples may illustrate the justification of the three terms. If out of ten very similar black-haired people only two become white by the usual process, whilst the others retain their colour, then these two diverge from the rest; but they do not, by the acquisition of the same new feature, become more alike each other than they were before. Only with reference to the rest do they seem to liken as they pass from black through grey to white, our mental process being biased by the more and more emphasised difference from the majority.

10 Ax Bx Cx D E F
9
8
7
6
5
4
3
2 Ax Bx
1 A B C D E F

Supposing A and B both acquire the character x and this continues through the next ten generations, while in the descendants of C the same character is invented in the tenth generation, and whilst the descendants of D, E F still remain unaltered. Then we should be strongly inclined, not only to key together $C\frac{x}{10}$ with A^{x}_{10} and B^{x}_{10}, but take this case for one of convergence, although it is really one of parallelism. If it did not sound so contradictory it might be called parallel divergence. The inventors diverge from the majority in the same direction: Isotely.

Third case.—Ten people, contemporaries, are alike but for the black or red hair. Black A turns white and Red E turns white, not through exactly identical stages, since E will pass through a reddish grey tinge. But the result is that A and E become actually more like each other than they were before. They *converge*, although they have gone in for exactly the same divergence with reference to the majority.

In all three cases the variations begin by divergence from the majority, but we can well imagine that all the members of an homogenous lot change orthogenetically (this term has been translated into the far less expressive 'rectigrade') in one direction, and if there be no lagging behind, they all reach precisely the same end. This would be a case of transmutation (true mutations in Waagen's and Scott's sense), producing new species without thereby increasing their number, whilst divergence always implies, at least potentially, increase of species, genera, families, &c.

If for argument's sake the mutations pass through the colours of the spectrum and if each colour be deemed sufficient to designate a species, then, if all the tenth generations have changed from green to yellow and those of the twentieth generation from yellow to red, the final number of species would be the same. And even if some lagged behind, or remained stationary, these epistatic species (Eimer) are produced by a process which is not the same as that of divergence or variation in the usual sense.

The two primary factors of evolution are Environment and Heredity. Environment is absolutely inseparable from any existing organism, which therefore must react (Adaptation) and at least some of these results gain enough momentum to be carried into the next generation (Heredity).

The life of an organism, with all its experiments and doings, is its Ontogeny, which may therefore be called the subject of Evolution, but not a factor. Nor is Selection a primary and necessary factor, since, being destructive, it invents nothing. It accounts, for instance, for the composition of the present fauna, but has not made its components. A subtle scholastic insinuation lurks in the plain statement that by ruthless elimination a black flock of pigeons can be produced, even that thereby the individuals have been made black. (But of course the breeder has thereby not invented the black pigment.)

There can be no evolution, progress, without response to stimulus, be this environmental or constitutional, *i.e.*, depending upon the composition and the correlated working of the various parts within the organism. Natural selection has but to favour this plasticity, by cutting out the non-yielding material, and through inheritance the adaptive material will be brought to such a state of plasticity that it is ready to yield to the spur of the moment, and the foundation of the same new organs will thereby be laid, whenever the same necessity calls for them. Here is a dilemma. On the one hand the organism benefits from the ancestral experience, on the other there applies to it de Rosa's law of the reduction of variability, which narrows the chances of change into fewer directions. But in these few the changes will proceed all the quicker and farther. Thus progress is assured, even Hypertely, which may be rendered by 'over-doing a good thing.'

Progress really proceeds by mutations, spoken of before, orthogenesis, and it would take place without selection and without necessarily benefiting the organism. It would be mere presumption that the seven-gilled shark is worse off than its six- or five-gilled relations; or to imagine that the newt with double trunk-veins suffers from this arrangement, which morphologically is undoubtedly inferior to the unpaired, azygous, &c., modifications. The fact that newts exist is proof that they are efficient in their way. Such orthogenetic changes are as predictable in their results as the river which tends to shorten its course to the direct line from its head waters to the sea. That is the river's entelechy and no more due to purpose or design than is the series of improvements from the many gill-bearing partitions of a shark to the fewer, and more highly finished comb-shaped gills of a Teleostean fish.

The success of adaptation, as measured by the morphological grade of perfection reached by an organ, seems to depend upon the phyletic age of the animal when it was first subjected to these 'temptations.' The younger the group, the higher is likely to be the perfection of an organic system, organ, or detail. This is not a platitude. The perfection attained does not depend merely upon the length of time available for the evolution of an organ. A recent Teleostean has had an infinitely longer time as a fish than a reptile, and this had a longer time than a mammal, and yet the same problem is solved in a neater, we might say in a more scientifically correct, way by a mammal than by a reptile, and the reptile in turn shows an advance in every detail in comparison with an amphibian, and so forth.

A few examples will suffice:—

The claws of reptiles and those of mammals; there are none in the amphibians, although some seem to want them badly, like the African frog *Gampsosteonyx*, but its cat-like claws, instead of being horny sheaths, are made out of the sharpened phalangeal bones which perforate the skin.

The simple contrivance of the rhinocerotic horn, introduced in Oligocene times, compared with the antlers of Miocene *Cervicornia* and these with the response made by the latest of Ruminants, the hollow-horned antelopes and cattle. The heel-joint; unless still generalised, it tends to become intertarsal (attempted in some Lizards, pronounced in some Dinosaurs and in the Birds) by fusion of the bones of the tarsus with those above and below, so that the tarsals act like epiphysial pads. Only in mammals epiphyses are universal. Tibia and fibula having their own, the pronounced joint is cruro-tarsal and all the tarsals could be used for a very compact, yet non-rigid arrangement. The advantage of a cap, not merely the introduction of a separate pad, is well recognised in engineering.

Why is it that mammalian material can produce what is denied to the lower classes? In other words, why are there still lower and middle classes? Why

have they not all by this time reached the same grade of perfection? Why not indeed, unless because every new group is less hampered by tradition, much of which must be discarded with the new departure; and some of its energy is set free to follow up this new course, straight, with ever-growing results, until in its turn this becomes an old rut out of which a new jolt leads once more into fresh fields.

The following Papers and Reports were then read :—

1. *The Hebridean* Diazona. *By* Professor W. A. Herdman, *F.R.S.*

Professor Herdman exhibited with remarks some specimens of the rare compound Ascidian *Diazona violacea*, which he had dredged recently in the Hebrides from his yacht *Runa*. When alive the colony is bright green, but when preserved in alcohol it becomes violet in colour. Specimens preserved in a solution of formol remain, however, unchanged in the green condition; and the two colours were shown to the Section side by side—the green (known formerly as 'Syntethys hebridica' of Forbes and Goodsir) and the violet (*Diazona violacea* Savigny), the form usually supplied to museums by the Zoological Station at Naples. The Hebridean and the Mediterranean forms are undoubtedly the same animal, and are exactly alike in minute structure. Professor Herdman was able to show that Hebridean specimens dredged from deep water when kept alive in sunlight changed their colour and gradually became darker and bluer, and finally acquired a slightly violet tint, although still in the living condition. The green colour is not due to chlorophyll, but to an allied pigment which has been described as 'Syntethein.' The chemistry of the change of colour to violet has not yet been explained.

2. *On the Bionomics of* Amphidinium operculatum *Clap. and Lach. By* R. Douglas Laurie, *M.A.*

A. operculatum occurs as brownish green patches on the sand just below high-water mark. These patches are sometimes clearly visible a hundred yards away, and yet a few hours later they may have so completely vanished, to about an eighth of an inch beneath the surface of the sand, that one would not suspect its presence on the shore at all. It was first recorded for the British Islands by Professor Herdman, who found it at Port Erin, Isle of Man, in 1911.

I found it on the Cheshire coast at Hoylake on February 9, 1913, and have made daily observations of its movements since and find that they show three periodicities.

(*a*) A daily periodicity. Very striking during the spring. For instance, during the latter half of February the patches were very evident on the surface of the sand on most days until 10 A.M., then they went gradually just below the surface, becoming entirely hidden from view at about 11 A.M., and so remaining until shortly after noon, when they once more gradually appeared, reaching a maximum about 2.0 P.M. which they retained until about 4.0 P.M. and then again disappeared. Two possible explanations of this daily periodicity suggest themselves: (i) expression of habit; (ii) a new direct response of the organism each day to daily recurring environmental stimuli. Experiments have been made which lead to the conclusion that the latter is the correct view, altered experimental conditions leading at once to correspondingly altered movements. The stimuli more immediately concerned are those of light and tide. Maximum light is by no means the optimum for *Amphidinium*, the optimum is a dull light. The reaction of the organisms is strongly negative to strong light, that is light which takes less than, say, ten seconds to colour the silver paper exposed in a Watkins 'Bee' photographic exposure meter; on the other hand, their reaction appears not negative but merely neutral to darkness. The conclusions based on experiment were confirmed by finding later in the year, as the days become longer, that the periodicity gradually changed, the morning maximum becoming earlier and the afternoon maximum later, so that in the latter half of May the brown patches were found to appear about 4.30 P.M. and in the latter half of June at about 7.0 P.M. The other important factor with which its daily movements are correlated is the tide, and the addition of this

factor explains certain apparent irregularities in the daily rhythm not described above, more particularly the behaviour of the organism during the night, upon which observations have also been made. Temperature does not appear important in the present connection.

(*b*) A lunar periodicity. *Amphidinium* lives not far below the high-water mark of spring tides, so that the neap tides do not reach it. A periodic alternation of 'spring' periods of activity and 'neap' periods of comparative inactivity is associated with the amount of water in the sand.

(*c*) An annual periodicity. There has been a considerable change in the appearance of the *Amphidinium* area as the year has advanced, apart from the changes recorded above. There was a strongly marked maximum from February to end of April, at which latter time the area reached its greatest size, being 40 yards across and extending along 220 yards of coast line, the whole composed of practically continuous smaller patches, appearing as a brown-green carpet on the shore, and very clearly visible a hundred yards away; during May the number began to decrease, the decrease became very marked during June, and they have not been seen on the surface of the sand since the first week in July, though up to the end of July a few are still to be found in samples of sand examined under the microscope. It is interesting to note that during the latter half of June numerous dead examples were found in the sand, which in dry warm weather had not been covered by the tide for several days.

Large elongated form. On July 6 a small patch about 6 inches square of a more yellowish tinge was noticed on the lower and damper margin of the area. It was composed of the larger, more elongated form found at Port Erin last autumn, another small patch appeared 30 yards away two days later, and two days later again numerous small patches were to be seen continuing up to the present time, gradually spreading seaward so as to cover a larger area which, however, is still small as compared with that occupied earlier in the year by the more rounded form. At present it appears each day at about 6.0 P.M. The whole area is well above the high-water mark of neap tides. This larger form replaced the smaller at Port Erin in autumn 1912, also two forms, which may be the two under consideration, were, I understand, found at Cullercoats by Meek this summer, and as Daniel and Hamilton have just found both forms on the West Coast of Ireland and Herdman on the Island of Iona it appears quite possible that they may be phases of the life cycle of the same organism. There is as yet no direct evidence of this. I am inclined to believe that the balance of what evidence there is points to their being different species.

The methods of migration of *A. operculatum* are elusive. It has not been found in any of the large numbers of tow-nettings taken by Professor Herdman, appearing to be essentially a sand dwelling form. I have kept cultures for a month in water without sand and found the water full of freely swimming organisms throughout this period, so that migration across seas is evidently quite feasible, and it is not necessary to its existence that it should live always between the tide marks.

The optimum light intensity for *Amphidinium* is not the same as for Convoluta, or for certain diatoms which I have observed at Hoylake and Port Erin, or as for euglinoids which I have watched at Port Erin, so that the periodic movements of these various organisms on the shore differ from each other in characteristic ways.

The bulk of the observations have been made at Hoylake, but I examined the rounded form at Port Erin during the first three weeks in April for purposes of comparison. At Port Erin *Amphidinium* lives a little lower on the shore than at Hoylake, so that it is covered even by neap tides. This is likely to involve well defined differences between its scheme of periodic movements and that of the Hoylake race.

N.B.—The colour of *A. operculatum* is due, as in crude chlorophyll, to two pigment groups. On shaking in an alcoholic extract with benzine these separate; one of them, more soluble in the benzine, is green and gives an absorption spectrum which falls within the limits of variation of the spectrum of the blue-green element in chlorophyll, while the other, which remains in the alcohol, has in an exaggerated condition the broad absorption band of the Xanthophyll type at the blue end of the spectrum.

3. *Report on the Occupation of a Table at the Zoological Station at Naples.*—See Reports, p. 153.

4. *Interim Report on the Biological Problems incidental to the Belmullet Whaling Station.*—See Reports, p. 154.

5. *Report on the Nomenclator Animalium Generum et Subgenerum.* See Reports, p. 153.

6. *Report on Zoology Organisation.*—See Reports, p. 154.

7. *Sixth Report on Experiments in Inheritance.*—See Reports, p. 155.

8. *Report on the Occupation of a Table at the Marine Laboratory, Plymouth.*—See Reports, p. 155.

9. *Fifth Report on the Feeding Habits of British Birds.*

10. *Report on the Formulation of a Definite System on which Collectors should record their Captures.*

11. *Report on the Natural History Survey of the Isle of Man.*

12. *The Larva of the Pin-cushion Starfish* (Porania pulvillus (O.F.M.). *By* Dr. JAMES F. GEMMILL.

The period of ripeness in the Firth of Clyde is from about the middle of April till about the end of May. The eggs are small, and development is indirect, the general larval history resembling that of *Asterias rubens.* The late larva is a brachiolaria with a well-marked sucker and numerous small papillæ on and between the brachia. This stage was reached in a culture eight weeks old which was made at the Millport Station and kept without change of water in a small aquarium holding about three-quarters of a gallon, under 'convection current' circulation at Glasgow University. Features of much interest are (1) the presence in early larvæ of possible rudiments of a posterior enterocœlic outgrowth; (2) the occurrence among the later larvæ of several specimens with double hydrocœle formation, and (3) the presence alike in normal and in double-hydrocœle larvæ of a 'madreporic' vesicle the floor of which contracts rhythmically during life.

13. *Mr. W. A. Lamborn's Observation on Marriage by Capture by a West African Wasp. A possible Explanation of the great Variability of certain Secondary Sexual Characters in Males.* *By* Professor E. B. POULTON, *F.R.S.*

A letter recently received from Mr. W. A. Lamborn, Entomologist to the Agricultural Department of Southern Nigeria, records the following interesting observation made near Ibadan :—

'On July 10, 1913, a large clay nest was found attached to the under side of a Kola leaf. On the nest was a large wasp which had enormously developed

mandibles, and flying to and fro close by were two other wasps. These last attempted to alight on the nest, but as soon as they did so the wasp in possession opened its jaws, buzzed angrily, and made a rush at them, whereon they beat a hurried retreat. This happened many times. Closer examination showed that the wasp was guarding a small hole at one side of the nest, at which I could see the head of a newly-emerged imago at work gradually enlarging the opening. . . . The confined imago made a sudden exit and fell, but the wasp on guard was so fully on the alert that it secured the falling insect with its legs and both came to the ground together. I am of opinion that it attempted to effect coitus, but in my anxiety to view satisfactorily the proceedings I approached too near, with the result that it took the alarm and flew up. I secured it, but the newly emerged wasp, the supposed female, escaped me. Meanwhile four more wasps were buzzing near the nest, and of these I managed to get two. I believe that these are males also, and I notice an astonishing difference in the degrees of mandibular development. The male with the largest pair obviously terrorised the others by virtue of possessing them, and, but for my interference, would have owed his success to this, for the case was definitely one of marriage by capture. The nest still contains three cells, and so I am hoping, if a female comes out, to be able to test for the assembling of males.'

It is impossible to imagine an observation that would have interested Charles Darwin more deeply than that recorded above by Mr. Lamborn.

There can be no doubt that the species of wasp is *Synagris cornuta* Linn., the very name of which obviously refers to the enormous horn-like outgrowth from the base of the mandible in some of the males. There is the same immense difference between the degrees of development spoken of by Mr. Lamborn, the outgrowth being of various sizes and sometimes only represented by a small tubercle. The females are very rare compared with the males—only one to about twenty in the British Museum of Natural History. Curiously enough, I had, only a few weeks ago, suggested observations on the part played in courtship by the mandibles of these very males to another friend who had brought specimens home with him from Sierra Leone, and was returning later in the year. But Mr. Lamborn, with his wonderful powers of observation, does not let much escape him.

It is suggested as a probable hypothesis that these immense horn-like outgrowths sticking straight out in front of the face are a disadvantage in obtaining food and perhaps in other ways in the struggle for life, and that the emergence of the females covers a period long enough for this struggle to tell, so that the males with small or rudimentary horns have the advantage in the end through the operation of natural selection, while the others have the advantage at the beginning through sexual selection, in the form of battles between the males.

I have written to Mr. Lamborn asking if he will carry out a series of observations in order to test this hypothesis.

A remark of the late Edward Saunders, F.R.S., the great Hymenopterist, will indicate the impression made by these extraordinary male characters which might be taken for 'monstrosities' did we not know that they are normally present in many males. We were glancing through the boxes of his father's collection in the Hope Department, at Oxford, when we came upon a male *S. cornuta*—a specimen from Fernando Po. 'Why,' said Edward Saunders, 'it is a biological education to look at that insect!'

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14. *Note on the Habits and Building Organ of the Tubicolous Polychæte Worm* Pectinaria (Lagis) Koreni, Mgr. *By* Arnold T. Watson, *F.L.S.*

The Amphictenidæ, of which family *Pectinaria Koreni* is a member, are admittedly the most skilful of marine tube-building worms. Their well-known tapering conical tubes, open at both ends, constructed generally of fine sand-grains, are examples of most exquisite and painstaking masonry. The worms are plentiful between half and extreme low tide marks on many sandy shores, through which they travel as was shown by the writer some nineteen years ago,

the small end protruding from and the wide end buried beneath the sand, the animal vigorously digging its way by means of the beautiful gold-coloured combs with which its head is endowed. In a memoir written in 1903 it was shown by Fauvel that the water necessary for respiration, and also for the purpose of stirring up the sand-grains beneath the surface, is, by a kind of peristaltic action of the animal, drawn or pumped through the tube, entering through the fine pointed end exposed above the surface, and often escaping to the surface of the sand through the fissures formed in the digging process. It was also observed by Fauvel that the worm has the power to reverse the direction of this current at will. It has hitherto been thought that the object of this reversed current was mainly to eject from the tube the sand which has passed through the animal's body, vigorous discharges from the small end of the tube being frequently noticed in the aquarium and attributed by the writer and others to this cause. Recent observations, however, have shown that this explanation is very far from complete, and that the discharge is an indication of a process going on underground, of the greatest importance to the operations and well-being of the worm.

The tube of *Pectinaria* is constantly growing by additions to its edge of grains of sand, most carefully fitted into place by the worm underground. In the marked state of commotion produced by the digging process, it would clearly be quite impossible for the worm to make the careful selection and adjustment of grains suitable to the requirements of each position, which is so manifest and marvellous in the finished tube.

For this purpose quiet and ample working space are needful. These requirements are secured at will by the worm, which ceases its digging operations at intervals, and obtains the needful working space in a way hitherto unsuspected. To this end, the sand underground surrounding the edge of the wide mouth of the tube must be got rid of. This is effected by a means similar to that adopted by dredgers for removing the sand from harbours—namely, by suction. After the ground has been broken up by the combs of the worm, and the neighbouring sand has been brought within reach and examined by the tentacles, the particles not required to be conveyed to the mouth for food are carried away by means of a very strong upward current, created within the tube by the peristaltic action already mentioned. This causes the sand to travel rapidly through the tube, passing between its wall and the dorsal surface of the worm, and to be ejected through the small end of the tube, thus forming the mounds on the surface of the sand which are generally visible in the neighbourhood.

In connection with the underground chamber thus formed, there is usually a shaft from the surface a short distance from the tube, and in the aquarium the opening of this shaft is frequently visible.

Hitherto the building organ of the worm appears to have escaped the notice of naturalists, but the writer has been more fortunate. It is centrally situated slightly below the ventral edge of the peristomium, and consists in its upper part of a pair of papillated downwardly directed lobes, which act in connection with a lower 'lip' formed by the delicate tissues just above the first ventral shield. In a specimen suitably prepared a cement-gland, liberally supplied with blood-vessels, and somewhat rosette-like in form (about 2 mm. in diameter), connected directly with the building organ, is visible by transparency.

In the light of methods observed and described by the writer with regard to other marine tubicolous worms, the above observations have, in his opinion, rendered the building operations of *Pectinaria* (which at one time seemed a hopeless problem) easily intelligible.

Though the act of building has never been seen, the process is doubtless as follows:—

A working space having been cleared by the method already described, a supply of sand is carried by the tentacles to the head of the worm. One portion of this sand, to be used for food, is swallowed, and passes through the body of the worm; a second portion is carried by the papillæ, which form a track, from the ventral edge of the peristomium to the building organ, just below. On reaching this organ each grain, which is accepted for building purposes, is received and held in the hollow between the two lobes. These lobes act as a pair of hands in combination with the 'lip,' and apply the sand-grain to the free edge

of the tube, where, having ascertained by an exquisite sense of touch the moment when an exact fit has been obtained, it is fixed by the cement which is poured out by the underlying cement-gland.

15. *The Influence of Osmotic Pressure on the Regeneration of* Gunda ulvæ. *By* Miss Dorothy Jordan Lloyd, *B.Sc.*

This work was carried out in the laboratory of the Marine Biological Association at Plymouth during the summers of 1912 and 1913.

G. ulvæ is a small triclad found in great numbers at Plymouth. It lives between the tide marks and near the borders of a small stream. The worms used in the experiments were all of the same size (5·5 mms. approx.). They were cut transversely into two equal halves. Only posterior regeneration is considered in this paper. The artificial waters used were made up by mixing known volumes of sea-water and distilled water, or, for the higher values, by mixing known volumes of sea-water and of a $2\frac{1}{2}$ molecular solution of sodium chloride. The osmotic pressure for any given salinity of sea-water was taken from Krummel's 'Handbuch der Ozeanographie.'

The following points were noticed :—

1. Whole worms can live indefinitely in water having an osmotic pressure between 2 and 33 atmospheres.
2. Regulation of an anterior half resulting in the production of a complete worm takes 50 days (at 15° C.) in water having an osmotic pressure between 15 and 22·5 atmospheres. (Osmotic pressure of sea-water = 22·5 atmospheres).
3. Lowering the osmotic pressure below 15 atmospheres retards the rate of regulation proportionately. Below five atmospheres pressure no regulation occurs.
4. Raising the osmotic pressure above 22·5 atmospheres retards the rate of regulation. Above 30 atmospheres no regulation occurs.
5. The new posterior region is formed by the migration of large numbers of parenchyma cells to the region of the wound, where they aggregate and build up the new organs. Inhibition of regulation seems due to some factor which checks the migration of the parenchyma cells.
6. In the worms showing retarded regulation irregularities in the mitotic divisions of the parenchyma cells have been noticed.

FRIDAY, SEPTEMBER 12.

The following Papers were read :—

1. *The Classification of the Pierines. By* Sir G. Kenrick.

2. *The Heredity of Melanism in Lepidoptera. By* W. Bowater, *B.D.S.*

Apparently the term melanism as applied to lepidoptera should be restricted to the substitution or increase of black on the wings or body, or both, at the expense of some other colour, but any darkening of the ground colour, although not black, has been included in a general way, although strictly the term melanochroism should be applied to the latter.

The list of species in which melanic specimens have been recorded is quite formidable, but many are merely cases of melanochroism.

The exemplary and very extensive experiments made on the London (dark) and French (light) forms of *Acidalia virgularia* by Messrs. Prout and Bacot [1] proved that these varieties are not Mendelian forms of the species, but Mr. W. B. Alexander demonstrated that the speckling of *virgularia* is dominant to non-speckling.

Experiments by Mr. Buckley on *Acidalia contiguaria* show that the dark form is dominant.

Messrs. Prout and Bacot found in another moth, *Triphæna* (*Agrostis*) *comes*

[1] *Proc. Roy. Soc.* Lond. 1909.

which has a melanic form, that segregation occurs, and that apparently melanism is a Mendelian dominant.

In the well-known case of the common Peppered Moth, *Amphidasys Betularia*, where the melanic form, unknown till about fifty years ago, has in this period multiplied and spread all over England and is now far commoner than the type, it seems without doubt due to the facts that melanism in this species is a dominant characteristic, and that it carries with it a real but not yet fully explained advantage in the struggle for existence.

Observations by various entomologists and a breeding experiment by the author also seem to point to Mendelian dominance, but the numerous intermediate forms obscure the issue, and at present complete experimental proof is not forthcoming.

Observations on breeding the melanic forms of *Aplecta nebulosa* and *Boarmia repandata* by Mr. Mansbridge seem to show that melanism follows Mendelian lines in these species, but the evidence is not yet conclusive.

With regard to the black form (*Varleyata*) of *Abraxas Grossulariata*, apparently the experiments have not been very extensive or prolonged, but it seems that in this species melanism follows Mendelian lines but is recessive.

In a paper entitled 'Melanism in Yorkshire Lepidoptera,' read by Mr. G. T. Porritt to this Section in 1906, he makes observations on the breeding of *Odontoptera bidentata* and its melanic form, and the author is convinced from his own experiment that the results can all be reconciled with the Mendelian Law of Heredity.

The author made the following experiment on *Odontoptera bidentata* :—

In November 1909 pupæ of both the type and melanic forms were obtained, and in the following April the imagines emerged and pairings were obtained of the pure strains and the resultant ova carried to maturity April 1911 (103 specimens).

From these, various pairings and cross pairings were made, and 13 families raised (403 specimens), 1912.

From these imagines further pairings and cross-pairings were made and 34 families were raised, comprising 1,000 specimens, with the offspring of which the experiment is now being continued.

Distinct segregation occurs, for although within both the type and the melanic forms there is a little variation in colour, there is no difficulty whatever in distinguishing between them at a glance. No specimens occurred which could be called intermediate.

The homozygous and heterozygous melanic forms are apparently indistinguishable to our eyes.

It was also shown that extracted types breed as true homozygotes, and there are eight families to show that two heterozygous blacks, if paired, give 75 per cent. black and 25 per cent type.

All possible varieties of pairings have been made, and if

MM = melanic (homozygous),
Mm = melanic (heterozygous),
and mm = type

the result in all the 50 families can be explained by the well-known Mendelian formulæ :—

$$\begin{aligned} MM \times MM &= MM \\ MM \times Mm &= MM + Mm \\ MM \times mm &= Mm \\ Mm \times Mm &= MM + Mm + mM + mm \\ Mm \times mm &= Mm + mm \\ mm \times mm &= mm \end{aligned}$$

All the actual specimens (1,800 in number), which were bred in the experiments are exhibited.

The author submitted with confidence that this experiment proves that melanism in this species is a simple Mendelian dominant.

In the other species the evidence is not extensive, as the experiments which have been made have seldom been carried beyond the second or, at any rate, the third, filial generation.

However, the weight of evidence seems to show that melanism in lepidoptera frequently follows the Mendelian law of heredity and in most cases is dominant, but in some few species seems to be recessive.

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3. *The Correlation of Pattern and Structure in the Ruralinæ Group of Butterflies. By* G. T. BETHUNE-BAKER, *F.L.S., F.Z.S.*

An exhibition was made showing changes in pattern, colour and structure in nearly allied genera in the Plebinæ, Strymoninæ, and Ruralinæ, also showing similar changes among species in the genera Plebeus and Ruralis. A further exhibit was also made of a few species of the genus Acrea, showing specimens that are very different superficially in colour, but their structure is very close; also showing other specimens where the pattern is very close, but the structure is very different. It must be borne in mind that as there are both generic and specific resemblances, so there are generic and specific differences, but they do not necessarily pass along parallel lines. Apparently small changes in pattern may be accompanied by a marked difference in structure, whilst a marked divergence in colour may be accompanied by a very slight change in structure. The latter, however, would probably be a specific rather than a generic difference. In the Ruralinæ the tegumen of the male armature is of dominant generic value, as also would be a great divergence of the aedoeagus or the harpagines; but small mutation in the two latter organs might merely indicate specific rather than generic difference.

So far as this special group of butterflies is concerned, there is no question on the point that change of structure is accompanied by change of pattern, or change of structure accompanies change of pattern. Reviewing all the data, the latter is probably correct, for colour and pattern seem more sensitive to mutability than structure. This shows itself particularly in the genera Ruralis and Heodes. In the former there are species that are brown, orange colour, blue, and metallic lustrous green, whilst the undersides follow two special lines of pattern. But it is scarcely possible to divide the genus, as the neuration and male armature prevent this being done. In the genus Heodes there are species of brilliant lustrous golden copper colour, and also of lustrous purplish. Here, again, however, the neuration is the same; but the male armature is evidently undergoing a certain phase of evolution. So that, though it may not be possible to divide the genus to-day, it is probable that ere long that will have to be done.

Other genera of butterflies that I have examined also bear out my contention. We have both the great genera Papilio and Charaxes, that naturally group themselves into sections, so far as their colour and pattern are concerned, this grouping being also followed considerably in their structural details. I am therefore led to believe that pattern is very generally correlated with structure in butterflies.

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4. *The Enemies of 'Protected' Insects; with Special Reference to* Acræa zetes. *By* Dr. G. D. H. CARPENTER.

Supporters of the theory of mimicry believe that certain insects escape being eaten by vertebrates generally on account of distastefulness, the possession of a sting, spines, &c. Such are said to be protected insects. This is not meant to imply protection against *every* enemy, or even against every vertebrate enemy. Such a state of affairs would soon bring itself to an end by the unlimited increase of such an insect. There is evidence that bee-eaters, for instance, prey especially upon such a typically protected insect as the honey-bee; that cuckoos prey especially upon hairy caterpillars shunned by other birds. But the enemies of protected insects that are of much importance are predaceous insects and parasites. I have seen in Uganda insects belonging to typically protected groups (Hymenoptera, Hemiptera, &c.) being preyed upon by predaceous insects.

Since of all the offspring on the average only two individuals will survive to carry on the race, insects which escape vertebrate enemies must be all the more destroyed by parasitic or predaceous insects. In the case of *Acræa zetes*—a typically 'protected' butterfly—out of seventy full-fed larvæ and pupæ obtained in Uganda, only sixteen, or 23 per cent., became butterflies, 77 per cent. being

destroyed by parasitic insects. Since all these had been collected when full-grown (*i.e.*, they had escaped the dangers of infancy), the destruction at all stages, including ova, is probably greater. So that less than 23 per cent. is all that is left for destruction by both predaceous insects and vertebrates.

The matter may be expressed as a formula. If X is the total number of offspring, then X–2= number destroyed by all influences. Putting P for those destroyed by predaceous insects, p for those succumbing to parasites, and V for those destroyed by vertebrates, then

$$V=(x-2)-(P+p)$$

V may thus be taken to indicate the degree of edibility to vertebrates, since the number destroyed by parasites, &c., must bear an inverse relation to the number destroyed by vertebrates. Could P (destruction by predaceous insects) be accurately estimated, a figure could be given for V, which might be called the edibility index; it would probably be found to be high for unprotected insects and the reverse for protected insects.

On the other hand an eminently edible insect may escape vertebrate foes through the perfection of its procryptic resemblance to its surroundings, or, according to the Batesian theory, of its mimetic resemblance. In this case V would be low, not because the insect was distasteful, but because it escaped attack; so that in the case of an insect known to be edible, V would be the index, not of edibility, but of success in disguise. Such insects would also be highly parasitised. In the case of the larvæ of the mother-of-pearl moth I believe V to represent the index of agility in escaping vertebrates. The larva is highly edible. Some years ago I collected large numbers as food for green lizards, which eagerly devoured them. But I found a very large proportion indeed were parasitised. The larva lives in a tube of nettle-leaf and is extremely adroit at escaping through one end of the tube directly the other end is investigated, and it seems likely that it must escape birds in this way.

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5. Pseudacræas *and their Acræine Models on Bugalla Island, Sesse, Lake Victoria. By* Dr. G. D. H. Carpenter.

In Uganda are four forms of the Nymphaline genus *Pseudacræa*, which I have shown by breeding to be of one species—namely, *Pseudacræa eurytus*, Linnæus, as was suggested by Dr. Karl Jordan. This species occurs in other forms in West and East Africa and in Natal; but everywhere closely mimetic of a *Planema* in that locality, being either sexually dimorphic or polymorphic, as the *Planema* is also dimorphic or polymorphic. The four Uganda forms are:

Hobleyi, mimicking *Planema macarista* (dimorphic).
Terra, mimicking *Planema tellus* (monomorphic).
Obscura, mimicking *Planema epæa paragea* (monomorphic).

There is also a female form of *hobleyi*, with almost the colouring of the male, which mimics *Planema poggei*, in which both sexes are alike. This *Planema* is also mimicked by another *Pseudacræa*—namely, *Ps. kunowi*. A collection of all these butterflies made without selection during 1912 and January-February 1913 on Bugalla Island, Lake Victoria, showed that the models were extremely scarce, the mimics of the species' eurytus extremely abundant and very variable, so that intermediates between the several types of *hobleyi*, *terra*, and *obscura* were very plentiful, thus :—

	Model		Mimic	
1	*Planema poggei* . .	2	*Pseudacræa künowi*	9
			Ps. eurytus, form *hobleyi*, ♀ with ♂ colouring	2
2	*Planema macarista* .	17	*Ps. eurytus*, form *hobleyi*	68
			Intermediates between *hobleyi terra* . .	75
3	*Planema tellus* . .	33	*Ps. eurytus*, form *terra*	103
			Intermediates between *terra* and *obscura* .	37
4	*Planema epæa paragea*	75	*Ps. eurytus*, form *obscura*	26
			Intermediates between *obscura* and *hobleyi*	45

In the case of *Planema epœa paragea* the model *is* more abundant than the mimic—due to the fact that I found a particularly good place for catching them when they were collected together. Generally they were very scarce.

In a very large collection of these same forms made by Mr. C. A. Wiggins at Entebbe, on the mainland twenty-five miles north-east of Bugalla, models are very abundant, as well as the mimics. The mimics, however, vary hardly at all. The suggested explanation is that on the mainland the models are sufficiently numerous for resemblance to them to have a definite selection value to the mimic, so that natural selection keeps them true to the type of the model.

On the island models are too scarce for it to be of any value to a mimic to resemble them; so that varieties persist which on the mainland are at a disadvantage, and are quickly destroyed by enemies. Stronger proof of the reality of mimicry and of the power of natural selection to maintain the mimetic likeness could hardly be desired.

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6. *The Geographical Relations of Mimicry. By* Dr. F. A. Dixey, *F.R.S.*

It is well known that certain definite schemes of colour and pattern in the wings of butterflies are characteristic of certain definite geographical regions. This is true not only of the region as a whole, but also, in many cases, of the smaller districts into which the given region may be divided, the colour and pattern undergoing a similar modification in all the members of the associated assemblage as one such district gives place to another.

Illustrations of this phenomenon are afforded by a well-known combination of red, black, and yellow Ithomiine, Heliconiine, Danaine, Nymphaline, and Pierine butterflies in Central and South America, and by a similar parallelism existing between local forms of the African genera *Mylothris* and *Phrissura*. The constituent members of these assemblages are often of very diverse affinities.

It is natural to seek for an explanation of these facts in the direction of a common influence exercised by the geographical environment. But in the special cases cited, to which many others might be added, this explanation is attended by such extreme difficulty as to be practically put out of court. The interpretation that at present holds the field is that which attributes these resemblances, with their correlated geographical modifications, to the action of mimicry, whether of the Batesian or Mullerian kind. This interpretation rationalises the geographical facts without resorting to the exceedingly difficult hypothesis of a direct influence by the geographical conditions.

If the interpretation under the theories of mimicry be accepted there still remain some anomalies to be accounted for. A few of these may be set down as mere coincidences, such as might be expected where the array of facts is so extensive; others are probably due to migration on the part of the insects themselves or of their enemies; while there is a residuum which no doubt points to the fact that somewhat similar schemes of colour and pattern may take independent origin in entirely distinct regions of the earth's surface, and may in each such situation become the common property of a Batesian or Mullerian mimetic assemblage.

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7. *Discussion on Mimicry.*

(i) *Mimicry. By* Professor E. B. Poulton, *F.R.S.*

Special attention was drawn to the relationship between birds and butterflies and to the examples of injuries actually *seen* to be inflicted by wild birds, and, in comparison, examples of injuries very commonly found in butterflies. Stress is to be laid on 'disabling injuries,' such as the loss of the whole of a wing, indicating that the insect had not escaped, but was abandoned after being mutilated. There is evidence to show that these injuries are especially characteristic of the great groups which supply the models for mimicry. The author pointed to the negative evidence derived from the examination of birds' stomachs, and exhibited pellets thrown up by birds after a meal of butterflies, showing how completely the nature of the food has been disguised. The author

showed illustrations and specimens of a few cases of mimicry in temperate North American butterflies, and pointed out what he believed to have been the evolutionary history. If this history be correct, then it is impossible to explain the resemblance as due to the influence of environment, because recent invaders from the Old World into this region have caused the mimetic modification of indigenous species. According to theory of environment the invaders ought to have been modified instead of the residents.

(ii) *Mimicry between the Genera of certain African Nymphaline Butterflies. By* Professor E. B. POULTON, *F.R.S.*

Although the models for butterfly mimicry in the Old World commonly belong to the great distasteful sub-families, the *Danainæ* and *Acræinæ*, they are also to be found among the groups in which we are accustomed to look for mimics rather than models. This is certainly true of the *Nymphalinæ*, in which the mimicry on both under and upper surface of the blue species of *Crenis* by *Crenidomimas* is as remarkable as any known example of such resemblances. The largest number of such instances, however, have been very little spoken of in works on mimicry, although recognised by Aurivillius. I refer to the mimicry of the species of *Catuna*, with both sexes alike, by the females of species of the allied genera *Euryphene*, *Diestogyna*, and *Cynandra*. The resemblance has another characteristic of mimicry in general, viz., the development of secondary resemblances between the mimics. Thus the likeness between the females of *Cynandra opis* and a *Diestogyna*, collected by Mr. S. A. Neave in Uganda, is positively startling. I have always hesitated to draw attention to these examples of mimicry until I knew more about the habits of models and mimics, but within quite recent years Mr. W. A. Lamborn, to whom I owe so much, has observed in the Lagos District that the mimics actually fly in the company of their models. Examples of models and mimics taken in one sweep of the net by Mr. Lamborn and others on which special observations have been made by him are exhibited to the Section.

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8. *The Term Mutation. By* Professor E. B. POULTON, *F.R.S.*

1. The word 'Mutation' was originally introduced by Waagen[1] to express a simultaneous and probably gradual change in a relatively large proportion of the individuals of the species, if not the whole species. 'Mutation' expresses the change itself, not the process by which it has been produced. Waagen nowhere states that his 'Mutations' are discontinuous variations or 'Saltations.' Waagen's material was exclusively palæontological, and his 'Mutations' are variations in time. He was inclined to believe that they were produced by a developmental force resident in the organism.

2. 'Mutation' was re-introduced by de Vries as equivalent to 'Saltation,'[2] and applied to Darwin's 'large' or 'single' variations as opposed to his 'individual differences.' The latter de Vries called 'Fluctuations.' According to de Vries as well as Darwin *both forms of variation are hereditary.* De Vries distinguished between them by supposing that a 'Mutation' leaps at once to a new position of genetic stability—it is what Galton previously called 'transilient.' De Vries' 'Fluctuations,' on the other hand, are subject to Galton's 'regression to mediocrity,' and there is a limit to the advance which can be achieved by selection.[3] It must be added that de Vries is disposed to explain 'Fluctuations' as due to the action of the

[1] 'Die Formenreihe des *Ammonites subradiatus*, &c.' *Geogn.-palaeont. Beiträge* ii, Heft 2, b (1869), p. 186.

[2] *The Mutation Theory*, Engl. Transl., Vol. i, London (1910), p. viii. 'These saltations, or mutations. . . .'

[3] *Ibid.* p. 123:—'Continued selection [of fluctuations] by no means fixes the character chosen, but, by separating the race further from the type from which it sprang, continually adds to the risk of regression.' This is precisely Galton's conclusion, just as 'Regression' in this sense is Galton's term. Darwin also 'fully recognised the limits which may be set to the results achieved by the artificial selection in one direction of individual variations,' and 'he admitted the necessity of waiting for a fresh "start in the same line."' (*Darwin and the Origin*, Poulton, London (1909), pp. 48, 49).

environment, and, so far as they are concerned, to accept the 'hereditary transmission of acquired characters.' The majority of biologists will prefer to conclude that de Vries' 'Fluctuations' are of two very different kinds, some of them being (*a*) Germinal characters that are hereditary, and subject to Galton's 'Regression'; and others (*b*) Somatic characters that are not hereditary. De Vries uses the term 'Mutation' to express (1) a single 'Saltation' and (2) the theory that evolution progresses dis continuously by means of 'Saltations.' He states, however, that his 'Mutations' may be small.[4]

3. Bateson, Punnett, Shipley and others have erroneously stated in recent years that de Vries 'pointed out the clear distinction between the impermanent and non-transmissible variations which he speaks of as *fluctuations*, and the permanent and transmissible variations which he calls *mutations*.'[5]

In this third use of 'Mutation'—Batesonian, not de Vriesian—the word is applied to any and every hereditary character and becomes the same as Weismann's 'Blastogenic Variation.' 'Fluctuation' similarly in this second use, restricted to (*b*) as explained above, becomes the same as Weismann's 'Somatogenic Variation.'

This mistaken reading of de Vries has unfortunately been widely followed, so that the Dutch botanist is now generally credited in this country with the bestowal of Waagen's term 'Mutation' upon a form of variation previously announced by Weismann, instead of upon one ('Transilient') previously announced by Galton.

The existing hopeless confusion can only be set right by restoring the term 'Mutation' to its rightful owner Waagen—a measure of justice for which geologists have been contending for several years.[6]

For the two other uses of 'Mutation' and for the two kinds of 'Fluctuation' the following changes are suggested:—

For 'Mutation' II. (de Vries), both large and small, substitute Galton's 'Transilient,' used as a substantive. The old associations of 'Saltation' are always with large variations, and the term should never be applied to small 'Transilients.' The term 'Magnigrade' to be used as substantive or adjective, may be conveniently applied to a 'Saltation' or 'Large Transilient,' 'Parvigrade,' similarly to a 'Small Transilient.' 'Magnigrade Evolution' is 'Discontinuous,' 'Parvigrade Evolution' 'Continuous.'

For 'Mutation' III. (Bateson *nec* de Vries) substitute 'Blastogen,' the substantive form of Weismann's 'Blastogenic.' Other synonyms are 'Constitutional,' 'Congenital,' 'Genetic,' 'Inborn,' 'Innate,' 'Inherent' and 'Centrifugal.' The term 'Variation' has also been used in this restricted sense.

For 'Fluctuation' I(*a*) (de Vries) substitute Galton's 'Regressive,' used as a substantive.

For 'Fluctuation' II. (Bateson) = I(*b*) (de Vries) substitute 'Somatogen,' the substantive form of Weismann's 'Somatogenic.' Other terms are 'Acquired' (going back to Erasmus Darwin, 1794, and Lamarck, 1809) antithetical to 'Inherent,' 'Centripetal' to 'Centrifugal,' and 'Modification' to 'Variation.'

The relationships are shown below:—

I. *Hereditary characters originating in the germ*	II. *Non-hereditary characters acquired by the body*
A. Blastogens	B. Somatogens
1. Transilients / 2. Regressives	
a Magnigrades / *b* Parvigrades.	

[4] *Ibid.*, p. 4.—'Of course every peculiarity of an organism arises from a previously existing one; not however by ordinary variation, but by a sudden though minute change, ... The name I propose to give to this "species-forming" variability is Mutability. . . . The changes brought about by it, the Mutations, ...'

So also on p. 55:—'. . . many mutations are smaller than the differences between extreme variants' [here used as equivalent to 'Fluctuations.']

[5] *Mendel's Principles of Heredity*, Bateson, Cambridge (1909), p. 287.

[6] F. A. Bather in J. E. Marr's Presidential Address to the Geological Society of London, 1905, *Proceedings*, pp. lxxii, lxxiii. In drawing up the present abstract I have received much kind help from my friend, Dr. Bather.

9. *A Case of Unilateral Development of Secondary Male Characters in a Pheasant; with Remarks on the Influence of Hormones in the Production of Secondary Sex Characters. By* C. I. BOND.

Description of Specimen.

The specimen shown is the skin of the White Ringed Formosan variety of the Chinese Pheasant.

The plumage on the left side is roughly that of the adult male. The left leg shows a well-marked spur. This is absent in the right leg.

The white-ringed neck feathers occur in a unilateral half-circle on the left side only.

The wing primaries and coverts are female in character with the exception of a few male feathers on the left side.

The tail coverts are of the male type.

The tail feathers (rectrices) show a unilateral assumption of the male pigmentary pattern on the uncovered side of each feather, there being no limitation of male plumage to the left side of the tail as a whole.

Examination of the Internal Organs.

A well-developed oviduct is present on the left side, and a sex organ occupies the usual situation of the left ovary.

Microscopic sections of different areas of this gland show that it is an ovi-testis. It consists of ovarian elements undergoing pigmentary degeneration and of testicular elements which show active growth.

This case presents a difficulty if we accept the ordinary or hormonic explanation of the origin of secondary sex characters.

Consideration of the following facts :—

(*a*) That the gradual destruction of ovarian tissue by disease or new growth in young individuals of the human species and birds is more frequently associated with the assumption of secondary male characters than the removal of the ovaries by castration.

(*b*) That islands of actively growing male elements can frequently be found in the degenerating ovaries of female individual birds which have assumed male characters.

(*c*) That secondary (male) sex characters can be arranged in groups which vary in the extent to which they are dependent on the internal secretion of the corresponding sex gland.

(*d*) The occurrence of hermaphrodite individuals in which the (somatic) secondary sex characters correspond with the constitution of the primary sex gland on the same side of the body.

All these facts suggest that *two* factors at least are concerned in the origin and development of secondary sex characters: one, a gametic factor—the primary sex gland, and the other a somatic factor. These two factors may vary independently of each other under certain conditions of abnormal hereditary transmission.

Analogy between the 'hormonic' theory of the origin of secondary sex characters, and the 'gametic factor' theory of the origin of 'unit' characters in the zygote.

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10. *Experiments on the Metamorphosis of the Axolotl. By* E. G. BOULENGER.

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11. *The Morphology of the Mammalian Tonsil. By* Miss M. L. HETT, *B.Sc.*

Tonsils are normally present in most of the mammalian orders, and do not atrophy till extreme old age, except in man. Though the physiological importance of the tonsil is at present undetermined, it has every appearance of a healthy

and functional organ. It is wanting in many rodents, some insectivores, and most bats.

Hammar derives the mammalian palatine tonsil from the dorsal diverticulum of the second gill-pouch. This would appear to hold good for Eutharia at all events, though Grünwald derives the human tonsil from the ventral diverticulum. Hammar divides tonsils into (*a*) primary and (*b*) secondary, according as to whether lymphoid tissue is laid down in the tuberculum tonsillare or not, placing man and the artiodactyla in the second division, and most other mammals in the first. This classification is at best somewhat arbitrary and presents several difficulties, *e.g.* :—

1. It is difficult to classify all tonsils on these lines, as there are numerous intermediate forms.
2. It is difficult to interpret the tonsils of primates other than man on this basis.
3. Although in man lymphoid tissue in the plica triangularis (=the tuberculum tonsillare) is secondary, yet the hypertrophy follows definitely anatomical lines, so that such tonsils may be classified under several distinct types.

Investigation of a large number of mammalian tonsils shows that the gross anatomy is very distinctive in each group, being always characteristic of the order, and frequently also of the family, or even, in some cases, of the genus. It is not easy to show an actual correlation between structure and habit in the case of this organ, but it is worthy of note that the carnivorous Marsupials have tonsils which bear a remarkable resemblance to those of Eutherian Carnivores.

MONDAY, SEPTEMBER 15.

The following Papers were read :—

1. *Pseudo-hermaphrodite Examples of* Daphnia pulex. *By* Dr. J. H. Ashworth.

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2. *Evolution of the Caudal Fin of Fishes.* *By* R. H. Whitehouse, *M.Sc.*

The diphycercal caudal fin of fishes may be primitively or secondarily symmetrical; the former is the protocercal type, and the latter the gephyrocercal. The diphycercal palæozoic fishes are usually considered gephyrocercal, but it is possible that they are survivors of the original protocercal form.

In the heterocercal form—e.g. *Heterodontus*—the anterior dorsal caudal radials are well removed from the neural arches, but they gradually approximate, and finally fuse together as the posterior end is approached. The same condition of things once occurred ventrally, but with the greater development of the ventral lobe, and the consequent necessity for a firmer support for the fin rays; the fusion took place further forward, and the gradual approach of radials to hæmal arches is not shown. Still, evidences of such fusion are frequently seen, and the hypurals of the fin are shown to be the result of a fusion of radial and hæmal arch.

Such evidences as these are interesting in connection with problems concerning the morphology of the various elements in the homocercal fin, which is nothing more than a specialised heterocercal form.

The urostyle, which is a fusion of a number of vertebræ, may be present as a slender rodlike bone, or it may be entirely suppressed. Owing to the overcrowding due to the excessive upturning of the caudal extremity, the epaxial arches of the urostyle are usually altogether suppressed; on the other hand, ventrally they remain and become greatly developed, owing to increased opportunities resulting from the upturning.

In the great majority of homocercal caudal fins dorsal fin-rays are supported by radials; this is interesting, as it shows that radials are more persistent than arches when subjected to adverse conditions, such as overcrowding.

There is abundant evidence to prove that the hypural elements in caudal fins are the result of fusion of hæmal arches with radials; perhaps the best examples illustrating this are members of the Gadidæ, where various conditions are seen, from free radials to fused hæmal arches and radials. Hæmal arches alone are unsuitable for the support of rays, and there seems no reason to suppose that elimination of suitable supports (radials) occurred in favour of arches in a position which offered every facility for greater development when we recall that, under adverse conditions dorsally, they persisted.

Differentiation of the median fins occurred before heterocercy was established, and in the specialised homocercal type the original caudal appears to have been suppressed and its place taken by the posterior anal fin brought relatively further back by the upturning of the caudal extremity.

Gephyrocercy is understood to refer to perfect external and internal symmetry secondarily acquired; *Fierasfer* is a good type. The whole of the original caudal has been lost, and the dorsal and anal fins have met round the abbreviated extremity and share equally the function of a caudal fin. Most probably the living Dipnoi are also gephyrocercal.

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3. *The Homology of the Gills in the Light of Experimental Investigations. By* Professor H. Braus.

The gills develop at a spot where ectoderm and entoderm meet. There have been many controversies on the question: which of the two germinal layers provides the *material* for the formation of the gills, or whether they both do so? But the fact that they are concerned in the formation of the gills does not tell us in which, if in either of them, lies the *determining factor* for gill-formation. Thus, for example, many authors have expressed the opinion that the mesoderm (vascular system) contains the primary formative factor. It would follow that the covering of the gills with epithelium is a passive process which could be performed in one case by the ectoderm, in another by the entoderm, according to the topographical circumstances.

The experimental method now gives us unequivocal information as to the *material* necessary for gill-formation and as to the *potencies* of this material. I refer to the results of a number of embryonic transplantations on the larvæ of anura (Bombinator, Rana, Hyla) performed in my laboratory by Dr. Ekman, of Helsingfors.

The gill-ectoderm was detached before the gills had formed, and was then transplanted to other parts of the organism. Gill-filaments afterwards developed from it, but no gill-clefts. Circulation of the blood was also wanting. The filaments soon perished, and in some species never became large. If the gill-ectoderm was lifted, turned round 180°, and replanted in that position at the same spot, gill-filaments were formed with circulation and gill-clefts. The latter were all twisted 180° from the normal position. This is very clearly seen in the operculum, which does not begin in front and grow backwards as usual, but in these cases begins behind and grows forwards. We may therefore conclude with certainty that the ectoderm alone is able to produce gills, and alone determines the position and form of these organs. The further development of the gills is dependent on the ingrowth of mesoderm (vascular system). A layer of entoderm beneath the ectoderm is sometimes present in the species examined, but not necessarily. *Foreign* ectoderm—*i.e.*, such as in ordinary circumstances does not develop gills—behaves differently, according to the part of the organism from which it is taken. If ectoderm is taken from the trunk or from the dorsal part of the head and planted in the position of the gill-ectoderm, no gills are formed, but a small opercular space appears for the anterior extremity. This is a consequence of the formative influence of the rudimentary limbs. If ectoderm is taken from the region above the embryonic heart and transplanted to the position of the gill-ectoderm, gill-filaments, gill-clefts, and an operculum are formed, as in the normal animal. The same effect is obtained from the *regenerated* ectoderm, which results when the ectoderm of the gill-region is extirpated and left to itself. It is not yet certain what factors induce this foreign ectoderm to assume the functions of ordinary gill-ectoderm, but a similar process has already been

observed by experiment on other rudimentary organs (lens-formation, bone-development). I have called it 'imitation,' and I regard it as of fundamental importance in relation to theories of homology.

4. *Discussion on Convergence in the Mammalia.*

(i) *Opening Remarks by* Dr. H. Gadow.

(ii) *Un nouveau cas de Convergence chez les Mammifères: Balæna et Neobalæna. Par le* Professeur Louis Dollo, *Sc.D., C.M.Z.S.*

Contrairement aux opinions reçues, *Neobalæna* n'est pas une vraie Baleine.

Elle n'est pas, non plus, intermédiaire entre les Baleines et les Balénoptères.

Mais c'est *une véritable Balenoptere,* simplement adaptée à la manière de vivre des Baleines.

Donc, un nouveau cas de *Convergence,* chez les Mammifères.

Les preuves à l'appui de cette assertion paraîtront dans les *Proceedings* de la Société Zoologique de Londres pour 1913.

(iii) *Convergence in Mammals. By* Professor Van Bemmelen.

Convergence is generally understood to mean the similarity between organisms not nearly related to each other—for instance, Cetacea and fishes, bats and birds, and so on. But there may—or, rather, there must—exist a far greater similarity, based on convergence, between near relatives. And it must be exceedingly difficult to distinguish this kind of convergence from the homologies caused by heredity; that is to say, by the influence of a common ancestor.

Yet it is clear that when, under equal influences of the environment and similar exigencies of the struggle for existence, organisms very different in original build are enabled to develop one and the same kind of new adaptations, the same must be the case in a far higher degree when nearly related organisms are subjected to those identical circumstances. To cite an example: our European mole is related to the shrew; the golden mole of the Cape, on the contrary, is a specialised offspring of the *Centetidæ.* Both have adapted themselves in a similar way to the subterranean mode of life. Is it then not probable that different species of shrews at various points of the earth, influenced by those similar life-conditions, might have been changed into different species or at least races of moles?

These possibilities must always be kept in view in all our speculations about evolution of new forms. Monophyletic origin, taken in its strictest sense, would always involve the highly improbable hypothesis of one single pair of individuals as the ancestors of each new species. As soon as we incline to the opposite opinion—the whole bulk of the individuals of a certain species all changing in the same way under the influence of changed external conditions of life into a new local race, variety, sub-species, and, finally, into a new species—we have admitted the existence of parallel evolution among near relatives.

Therefore I am convinced that all studies on convergence must start with the careful comparative investigation of those nearest relatives. To cite an example: Some years ago I took up the question of the relationship between the hare and the rabbit. Is the first an offspring of the second, or *vice versa,* or have both derived from a common ancestral form, more generalised and more like the rest of the Duplicidentata (and also more like the Simplicidentata)? With many restrictions, I believe the second assumption to be the most probable; but what interests us here is the conclusion I arrived at in comparing not only the European hare to our rabbit, but more generally the different sub-genera of the genus *Lepus* to each other. I found myself obliged to assume that the adaptation of a free-living hare-like Duplicidentate to a fossorial subterranean mode of life had taken place several times in different parts of the world, and

in different geological epochs, so that all rabbit-like members of the family did not form one well-circumscribed group as opposed to the hare-like ones, but, on the contrary, they represented a number of independent side branches emerging on different levels from a central stem, that itself leads from primitive hares like the Sumatran short-eared hare called *Nesolagus netscheri*, to the highest developed species, as *Lepus europæus*. Thus the hispid hare of Bengal, living on the southern slopes of the Himalayas, known as *Caprolagus hispidus*, according to my views, is to be considered as a rabbit-like offspring of primitive short-eared hares still represented by Nesolagus.

Another group of mammals about which I may presume to pronounce personal judgment are the Monotremes. Ornithorhynchus and Echidna are both highly specialised forms, whose more generalised ancestors have all disappeared from the globe, and their similarities in many points are the consequence of convergence instead of homology. So it is by general consent with the loss of their teeth, but, according to my view, the same is the case with the retrogression of their internal nares and the corresponding elongation of their bony mouth-roof. Ornithorhynchus acquired these features on account of its amphibian habits, as was the case with the crocodiles or the Cetacea. Echidna, on the contrary, developed them under the influence of its ant-diet, as did the South American ant-eaters and the aardvark of the Cape. Yet the arrangement of the bones in these osseous roofs of the mouth-cavity shows a similarity of primitive character, which, without doubt, depends on common ancestry, and therefore may be used in phylogenetic speculations. The same is true of many other features; for instance, the annular tympanic bone, the large malleus, the unperforated stapes, the possession of marsupial bones, the number, position, and anatomical structure of the milk glands, and so on. In my opinion, the phenomena of convergence, even in nearly related organisms, will never prove to be a serious obstacle to the disentangling of phylogeny.

(iv) *Convergence and Allied Phenomena in the Mammalia.* *By* W. K. Gregory, *Ph.D.*

In his monograph on the Shoulder-girdle of the Vertebrata the late W. K. Parker spoke scornfully of the study of Adaptation. A teleological explanation, he said, is an impertinence in a morphological work; and again: 'Teleology is a pretty golden ball that diverts the racer from his course.' But at present it is coming to be realised that studies on Adaptation (of which Convergence is a special case) must be thoroughly synthetised with morphology, general phyletic relations, and taxonomy.

The frequency of homoplastic resemblances and the discovery that certain systematic groups are unnatural should lead to no pessimistic views regarding classification and phylogeny in general, but rather to encouragement. For, at least in every case which I have thoroughly studied, Convergence never leads to a complete agreement in underlying ordinal or subordinal characters between convergent forms of widely different ancestry. By close study of the skeleton and soft parts the many little things that reveal the true phylogenetic positions of the convergent forms become apparent.

Specimens of the skulls of the Marsupial Wolf *Thylacinus* and of the ordinary wolf were exhibited, and it was argued that, notwithstanding the marked 'cænotelic' resemblances, the 'palæotelic' differences showed conclusively that one was a Marsupial, the other a Placental. Similarly the 'cænotelic' characters of *Notoryctes* give it a marked general resemblance to *Chrysochloris*, but the palæotelic characters of the two forms show that one is a specialised Polyprotodont Marsupial, the other a specialised Zalambdodont Insectivore.

The totality of the cænotelic or recent adaptive characters of an animal may be called its *habitus*; the totality of its palæotelic characters may be referred to as its *heritage*. The habitus tends to conceal remote phylogenetic relationships, the heritage to reveal them. Thus, the diverse habitus of *Thylacinus*, *Notoryctes*, and *Phaseolomys* concealed their remarkably uniform underlying heritage.

In many cases of Convergence there is a likeness of material or a general homology to begin with, as in the evolution of the Carnassial teeth in the

Hyænodontidæ and Canidæ, where, although the evolution had taken place in different teeth (the fourth upper premolar in the Canidæ, the second upper molar in the Hyænodontidæ), yet the tissues involved were the same in the converging groups; but sometimes convergence took place between structures formed from quite different tissues, as in the dentition of *Thylocoleo* and the not dissimilar piercing and shearing structures of *Dinichthys*; in the former case true teeth, in the latter only sharpened edges of bone were involved.

Professor Anthony, of Paris, in his excellent work on arboreal adaptation in vertebrates suggests that many of our orders, sub-orders, and families may be 'groupings by Convergence'; but in the classification of the Mammalia great strides have already been made in the detection of cases of Convergence, as, for example, in the case of the extinct Patagonian Sparassodonts.

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5. *Recent Investigations on Parasitic and other Eelworms.* *By* GILBERT E. JOHNSON, *M.Sc.*

Nothing is yet known of the mode of nutrition of the free-living species of the *Anguillulidæ*, save of those which are found feeding saprozoically on substances putrefying in the soil or in water, or which develop in enormous numbers on artificial food-media allowed to decay on samples of soil. These species, the majority of which belong to the genus *Rhabditis*, and are well suited to artificial cultivation, find their nourishment among the swarms of bacteria which develop in such media and multiply rapidly under these conditions, though whether they feed on the bacteria themselves or on the products of their action is not yet known. The nonsaprophytic free-living species, though incapable of being maintained under cultural conditions, may derive their nourishment from similar sources but in smaller quantities.

Those few species of the *Anguillulidæ* which have been described as parasitic in animals, and of which *Rhabditis pellio* is the best example, are probably not parasites in the strictest sense. *Rh. pellio* inhabits the common earthworm, *Lumbricus terrestris*, being found in the nephridia in an active, and in the cælomic cavity in an encysted, larval condition. In this state the larvæ remain without growth or change until the death and decay of the earthworm, when they grow rapidly, mature, and reproduce. *Rh. pellio*, though nominally a parasite, is thus comparable in its mode of life with the saprozoic species living free in the soil, for it derives the nourishment for its growth from decaying organic matter and uses the living earthworm only as a shelter during that period when growth is at a standstill.

The species parasitic in plants (*Tylenchus*, *Aphelenchus*, and *Heterodera*), pierce the cellular tissue of the plant by means of the hollow stylet protrusible from the mouth-cavity and absorb the cell-sap. There are, however, in addition to the parasites a large number of 'semi-parasitic' species, which occur in constant association with the perfectly healthy plant. They are found chiefly round the roots, but, in the case of seedlings of cereal and other grasses, occur also between the leaf-sheaths and within the grain from which the seedling is growing. Almost all plants appear to have these semi-parasites round their roots, attracted from the surrounding soil, which is relatively poor in nematodes. The problem: On what do these semi-parasites feed? remains unsolved. Not on the living cells of the root, for most of the semi-parasitic forms are unarmed, and the roots are undamaged. Do they feed on bacteria collected round the roots? If they feed on bacteria useful to plant growth, they may fill a rôle similar to that of the *Protozoa* of the soil, whose harmful activity can be checked by the expedient of 'partial sterilisation.'

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6. *Some Aspects of the Sleeping Sickness Problem.* *By* Professor E. A. MINCHIN, *F.R.S.*

TUESDAY, SEPTEMBER 16.

The following Papers were read :—

1. *Living Cultures of the Embryonic Heart shown by the Micro-Kinematograph. By* Professor H. Braus.

Harrison's discovery that individual cells and whole organs of the embryo may be isolated and cultivated in a cover-glass—*i.e.*, made to grow outside the organism—is now well known. It may, however, be of some interest to see the phenomena of growth and movement demonstrated, if not in the actual living cultures which I have shown elsewhere,[1] at least in the kinematograph. Micro-biographs were taken in order to exhibit delicate phenomena of movement that were too rapid or too slow to be appreciated by simple inspection.

The beating heart exhibited is that of a frog larva (*Rana esculenta*) six millimetres long. At this stage the heart is only just perceivable as a tiny dot upon a black background; its pulsation can be recognised only by magnifying it. In form it is an S-shaped tube. In the cultures the shape and also the diameter of this tube gradually change.

When the photographs were taken this preparation was seven days old, yet the regular rhythm of pulsation is the same as on the first day—viz., about eighty beats per minute.

The movement is peristaltic. Pulsation of the sinus, atrium, ventricle and bulbus can be clearly distinguished. Under the influence of chemical rays disturbances (suspension and irregularity) are caused during the exhibit. There are also typical 'refractory' periods in certain cases.

To prove that the preparation is really growing I have photographed some of its pigment cells on a larger scale. The micro-biographs were taken at intervals of ten minutes, on the average, during a period of ten hours. It takes only a few minutes to show them on the screen, so that the movements (increase in thickness, amœboid movement of the processes, shifting of the cells *in toto*) seem to take place rapidly.

The heart has no ganglion cells either at the beginning or at the end of the experiment. It consists of two epithelial membranes: the endocardium and an exterior layer, the visceral mesoderm. Every cell can be thoroughly inspected in control-preparations, and by a series of sections of hardened cultures. As the cells lie in a compact layer, ganglion cells are certainly not present. Nerves proper are still a long way off. The vagus has only a short, stumpy *Ramus intestinalis*, which follows the intestine only slightly, but cannot be removed with the heart. The sympathicus is at this stage represented by mere traces near the aorta, and therefore not present in the preparation. Experiments with glass-culture of nerves, however, show that real nerves do not originate, except by growth from the central neuroblasts.

Nor can it be the muscles that conduct the stimulus, for the heart cultivated *in vitro* possesses at first no cross-striping and no muscle cells that are microscopically distinguishable. Yet there *is* conveyance of stimulus beyond doubt, as seen in the disturbances of co-ordination—*e.g.*, in a 'refractory' period. The plasmoderms, therefore, the protoplasmatic links between the cells, must be the conductors of the stimulus.

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2. *The Scottish Zoological Park. By* Dr. W. S. Bruce, *F.R.S.E.*

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3. *Joint Meeting with Sections I and K.*

Synthesis of Organic Matter by Sunlight in Presence of Inorganic Colloids, and its Relationship to the Origin of Life. By Professor Benjamin Moore, *F.R.S., and* Arthur Webster.

The whole world of living plants and animals depends for its present continuance upon the synthesis of organic compounds from inorganic by the green

[1] Naturwiss. Mediz. Verein, Heidelberg, July 11, 1911 (*Münchener Mediz. Wochenschrift*).

colouring matter of the plant acting as a transformer of light energy into chemical energy.

A little reflection shows that this present state of affairs must have evolved in complexity from something more simple existing at the commencement. For chlorophyll, which now acts as the transformer, is itself one of the most complex of known organic substances, and could not have been the first organic substance to evolve from inorganic matter.

In considering the origin of life, the start must be made in a purely inorganic world without a trace of organic matter, either plant or animal.

As Schafer has pointed out, any other supposition merely removes the seat of origin to some conveniently remote planet, and pushes the origin back farther in time, but brings us no nearer to a real solution.

The earlier theories and views as to spontaneous generation all possess the error of attempting to start life amidst organic nutritive material which could not be there until life had already appeared.

The complex organic substances, such as carbohydrates, fats, proteins, and all the many other organic cell constituents, are late products along the line of evolution of life, and the beginning lies at a level much below that of the bacterium or diatom.

As a result of about eighteen months of experimental work, we have, we believe, obtained evidence of the first organic step in the evolution.

When dilute solutions of colloidal ferric hydroxide, or the corresponding uranium compound, are exposed to strong sunlight, or the light of a mercury arc, there are synthesised the same organic compounds which are at present formed as the first stage in the process of organic synthesis by the green plant, namely, formaldehyde and formic acid.

If now we consider a planet exposed to the proper conditions of temperature and sunlight, that chain of events can be followed, which not only can but must occur. At first, as the planet cools down, only elements would be present, at a lower temperature binary compounds form, next simple crystalloidal salts arise. Then, by the union of single molecules into groups of fifty or sixty, colloidal aggregates appear. As these colloidal aggregates increase in complexity, they also become more delicately balanced in structure, and are meta-stable or labile, that is, they are easily destroyed by sudden changes in environment, but, within certain limits, are peculiarly sensitive to energy changes, and can take up energy in one form and transform it into another.

This is the stage at which we take the matter up in our work. These labile colloids take up water and carbon dioxide, and, utilising the sunlight streaming upon the plant, produce the simplest organic structures.

Next these simpler organic structures, reacting with themselves, and with nitrogenous inorganic matter, continue the process and build up more and more complex, and also more labile, organic colloids, until finally these acquire the property of transforming light energy into chemical energy.

The problem of the origin of life hence acquires, as stated by one of us at the Dundee meeting of the Association, the aspect of an experimental inquiry with vast opportunities for obtaining more exact knowledge.

From this first step in the organic synthesis advance must be made to study how more and more complex organic compounds can be evolved.

But it is clear that by the continued action of this 'law of molecular complexity' life must originate, that forms of life are now originating, that the origin of life was no fortuitous accident, and that the same processes are guiding life onwards to higher evolution in a progressive creation.

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4. *On the Phylogeny of the Carapace and on the Affinities of the Leathery Turtle, Dermochelys Coriacea. By* Professor J. Versluys. See Appendix, p. 791.

5. *On the Oviposition of* Urophora solstitialis, *Linn.* *By* J. T. Wadsworth.

The Trypetid fly *Urophora solstitialis*, Linn., whose larvæ induce galls in the flower-heads of *Centaurea nigra*, Linn. and allied Composites, possesses a very efficient piercing ovipositor. Piercing ovipositors are comparatively rare in Diptera. The ovipositor of *U. solstitialis* exhibits three well-marked segments: a fixed outer segment, and an inner portion, capable of extension and retraction, composed of the other two segments. The first segment serves as a sheath for the other two segments when they are retracted; it also contains the lower free portion of the oviduct, the retractor muscles of the ovipositor, and muscles which probably assist in the process of extension. The second segment is flexible and capable of being protruded and retracted like a glove-finger. The third and last segment is the actual piercing portion; it is a chitinous tube, and bears the terminal portion of the oviduct, which opens to the exterior within a short distance of the tip. The extended ovipositor is retracted by special muscles, which are inserted at the junction of the flexible middle segment with the chitinous terminal portion.

The complete ovipositor, when extended, is nearly twice the length of the fly. During oviposition the abdomen is pushed down between the bases of the lowest and outermost bracts of the flower-heads, and, whilst in this position, the piercing portion is forced into the tissue of the receptacle. The ovipositor passes downwards and inwards towards the axis of the flower-head, and then gradually bends upwards until the tip of the ovipositor is finally in the space between the top of the young florets and the overlying bracts. The ova are usually placed in this space; occasionally, however, they may be found between the young florets. The larva after hatching bores a hole in the corolla of a young floret and travels downward to the ovary. It enters the ovary, feeds on the developing ovule and surrounding tissues, and its activities in this position lead to the growth of the 'gall.'

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6. *Exhibition of a Fossil Skeleton of* Notharctus rostratus, *an American Eocene Lemur, with remarks on the Phylogeny of the Primates. By* W. K. Gregory, *Ph.D.*

Owing to the scarcity of the material, the relationship of *Notharctus* and allied Eocene genera to modern Lemurs was long in doubt. The discovery of several partial skeletons in the Bridges Basin of Wyoming by the American Museum of Natural History affords a fairly complete knowledge of the skull, dentition, limbs, and vertebræ. The material shows that *Notharctus* is a primitive Lemur, more primitive than any now living, and possibly ancestral to the Indrisine Lemurs. The correspondence of the details of the limbs, &c., between *Notharctus* and modern Lemuridæ is remarkably close. The front teeth are more primitive, and have not yet assumed the lemurid characters; the molars are in pattern ancestral to those of *Propithecus*.

The supposed systematic and phylogenetic relationships are summarised in the following classification of the Primates :—

A. Lemuroidea :—
- I. Prolemures :
  - Notharctidæ.
  - Adapidæ.
- II. Lemures :[1]
  - Lemuridæ.
  - Indrisidæ.
  - Archæolemuridæ.
  - Chiromyidæ.
- III. Nycticebi :
  - Nycticebidæ.

B. Pseudolemuroidea :—
- IV. Tarsii :
  - Anaptomoriphidiæ.
  - Omomyinæ.
  - Anaptomorphinæ.
  - Necrolemurinæ.
  - Tarsiidæ.
- V ? Mixodectini :
  - Mixodectidæ.

C. Anthropoidea :—
- VI. Platyrhini :
  - Hapalidæ.
  - Cebidæ.
- VII. Catarhini :
  - Parapithecidæ.
  - Cercopithecidæ.
  - Simiidæ.
  - Horninidæ.

The Prolemurs are the lowest and more generalised of all Primates, and contain the ancestors of the Adapidæ, Lemuridæ, Indrisidæ.

The Lemurs include the highly varied Malagasy forms, which all have procumbent lower incisors, incisiform canines, and more or less caniniform premolars. The tympanic annulus is typically a mere ring completely within the bulla, the molar touches the lacrymal, the pes is essentially as in *Lemur*.

Nesopithecus and other ape-like lemurs, with enlarged brain-case, are closely allied to the Indrisidæ, and their resemblances to the Anthropoidea are demonstrably convergent, not genetic. *Chiromys* is rather nearly related to *Archæolemur*. Its enlarged lower front teeth are probably canines, not incisors. *Palæopropithecus* is not an Indrisid, but is related to *Megaladapis*. The Nycticebi are sharply separated from the Malagasy *Lemurs*, especially in the basicranial region, which is more specialised than in typical Lemurs.

Tarsius, together with *Anaptomorphus*, *Omomys*, *Necrolemur*, and their allies, is probably intermediate between the Lemurs and Anthropoids as held by Wortman, Schlosser, and others. The Omomyinæ may have given rise to the South American Primates as suggested by Wortman. The oldest known Platyrhine *Homunculus* of the Patagonian Santa Cruz formation is definitely a Cebid. The oldest Anthropoidea are the primitive genera described by Schlosser from the Upper Eocene of Egypt. They show no special approach to the Platyrhines. In the pattern of the premolars and molars, as well as in the number and kinds of teeth, they are foreshadowed by the Mixodectidæ of doubtful affinity, but these have specialised incisors. The Hominidæ are securely linked with the Simiidæ, not only by the abundant evidence of anatomy, physiology, &c., but also by recent palæontological discovery.

7. *On a Mammal-like Dental Succession in a Cynodont Reptile. By* R. Broom, *D.Sc.*

The author exhibited specimens of the upper and lower jaws of a small species of *Diademodon*. The specimen is not quite adult, as may be seen in the fact that the last molar is not yet through to the surface. After death and before fossilisation considerable maceration has evidently taken place, resulting in most of the teeth having fallen out. All the functional teeth of the upper jaw and most of the anterior teeth of the lower are lost. But in the sockets of the two upper and two lower canines of one upper incisor and one lower premolar are seen the crowns of replacing teeth. There is no evidence of any replacing teeth in the sockets of the true molars above.

From the evidence we may conclude that the Cynodonts had deciduous incisors, deciduous canines, and four deciduous premolars, exactly as in mammals. As there is no evidence in any specimen of a dental succession after maturity is reached, we may further conclude that the two sets of teeth correspond to the mammalian milk set and permanent set.

8. Thaumastotherium osborni, *a New Genus of Perissodactyles presenting some Unusual Features. By* C. Forster Cooper.

WEDNESDAY, SEPTEMBER 17.

The following Papers were read :—

1. *The Organisms of Brine Cultures. By* T. J. Evans.

Experiments were made to re-examine the variation of *Artemia salina* in graded strengths of salt-solution from 4 to 25 per cent. Solutions of Tidman's sea-salt were employed and placed in a good light. Contrary to Calman's results (1911), it was found that the *Artemia* in 8 and 10 per cent. attained maturity without the introduction of extraneous food. The food supply was *Chlamydomonas* (sp.?) in various stages of its life-cycle. Further, the nauplius stages of *Artemia* die unless the brine contains a supply of free-swimming monads; but the adult animal lives on the resting palmella and encysted stages which occur

on the sides of the vessel and among the bacteria in the surface film. The surface film food-source is so prolific that the *Artemia* spends much of its time feeding on it, and it is probable that the habit of swimming on its back adopted by *Artemia* is an adaptation for feeding in the surface film.

In the lower strengths, 4 and 5, and in the higher, 20 and 25, either the eggs did not hatch or the young nauplii died as soon as the shell burst. Adults transferred from the optimum solutions 8 and 10 lived in the lower and higher strengths, and the eggs laid in these solutions by them lived and grew. This suggests that the cause of death in these extreme strengths in the first case was the sudden change in the osmotic pressure, since eggs will hatch in any solution in which they have been formed.

No variation in the order described by Schmankiwitch was found in the second and third generations; the tail lobes were of uniform size in all strengths and possessed 8 spines on either side. It is probable therefore that variation is reduced to a minimum when the conditions and the relative percentages of the salt constituents in the solutions are constant, the variation in the total salt content of the water playing little part in the production of variations in structure.

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2. *A* Chalcid *Parasitic on Thrips* (Thysanoptera). *By* Richard S. Bagnall, *F.L.S.*

For some time now Thrips have been regarded as insects of considerable economic importance, and on that account have formed the subject of considerable research. Yet it was only in 1911 that a parasite of any importance was discovered, when Mr. H. M. Russell reared a Hymenopterous insect belonging to the Chalcidæ from the prepupa of *Heliothrips fasciatus* Pergande, which Mr J. C. Crawford has described as a new genus and species, *Thripoctenus russelli.*

Mr. Russell last year published the results of numerous experiments carried out on this parasite, showing that it reproduces parthenogenetically and would oviposit in the larvæ of several species of Thrips belonging to the sub-order Terebrantia, such as *Thrips tabaci*, *Frankliniella tritici*, but would not attempt oviposition in the larvæ of a species belonging to the sub-order Tubulifera, and also refused to oviposit in the young of a bug and of Aphides.

In the same year (1911) G. del Guercio reported upon a Chalcid parasite of a species of Tubulifera, the Olive Thrips (*Phlœothrips oleæ* Costa), which in a later paper he named *Tetrastichus gentilii*, stating that both sexes occurred.

With these exceptions only one other Thrips parasite has been named, when, in 1860, Mrs. Charlotte Taylor described one from Thrips on wheat, under the name of *Pezomachus thripites*, a small, wingless creature, with multi-articulate antennæ and two thoracic nodes. This has not since been recognised.

For some time I have observed a minute black and white Chalcid parasite which I have always regarded as having some connection with Terebrantian Thysanoptera. In August of this year (1913) I found many specimens of this Chalcid in the flowers of the toad-flax (*Linaria*) at Hele Bay, near Ilfracombe, which were obviously interested in Thrips larvæ (*Tæniothrips primulæ* chiefly, and *Physothrips atratus*), and the following morning, by a curious coincidence, I received a long-promised tube of *Thripoctenus russelli* from Mr. Russell. An examination of my captures showed that they belonged to the genus *Thripoctenus*, and almost certainly to the American species, *russelli*, though I propose submitting it to the describer, Mr. Crawford.

British distribution of *Thripoctenus russelli*: August 1913, with *Tæniothrips primulæ* and *Physothrips atratus* in toad-flax (*Linaria*), Hele Bay, near Ilfracombe; with *Oxythrips parviceps* and *Physothrips ericæ* in heather on the Tors, near Ilfracombe, and with *Thrips tabaci*, *Frankliniella intonsa* and *Thrips palustris* in the louse-wort (*Pedicularia palustris*) at Hogley Bog, Cowley, near Oxford.

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3. *On the Systematic Position of the Order* Protura. *By* Richard S. Bagnall, *F.L.S.*

The Order *Protura*, diagnosed by Silvestri in 1907 and monographed by Berlese two years later, on account of its anomalous nature and curious morpho-

logical features, has formed the subject of many discourses as to its position in the Arthropod classification.

The important and essential characteristics were reviewed and the views of various authors discussed as to its relationship with the Myriapoda and *Insecta.* The reader deplored the use of the term *Myriapoda* to represent what was not a class but a convenient assemblage of 'many-legged' arthropods, and restricted his remarks to the one so-called Myriapod Order, *Chilopoda,* or Centipedes, highly organised Arthropods coming near to the *Insecta.* He considered that whilst the *Protura* had affinities with the *Chilopoda,* especially *Lithobius,* in the larger number of body-segments and the position of the genital opening, the weight of evidence lay in favour of modifying the classification of the insect, dividing it into two sub-classes, the one to include *Protura,* and the other to include all other Orders of insects.

4. *The Early Evolution of the Amphibia. By* D. M. S. WATSON.

In the Lower Carboniferous and Productive Coal Measures of England all the known large Amphibia agree in the following features : The main articulation of the skull with the vertebral column is by a single large concave basioccipital condyle, the pterygoids articulate with small ventrally directed basipterygoid processes of the basisphenoid, the parasphenoid is small, and the interpterygoid vacuities practically absent. The vertebral column is throughout embolomerous. In two types the exoccipitals articulate with the vertebral column, in one case by very small separate facets, in the other by combining with the much larger basioccipital to form a tripartite condyle. In the large Permian Amphibia the articulation of the skull is by two large exoccipital condyles, but the basioccipital is still still of reasonable size, and may perhaps in some cases articulate with the atlas. The pterygoids articulate with much exaggerated and in the main laterally directed basipterygoid processes formed by the otherwise much-reduced basiphenoid, which is supported by the enlarged parasphenoid. The interpterygoid vacuities are much enlarged. The vertebral column is rachitomous—a condition which is derived from the embolomerous by the squeezing out of the lower part of the pleurocentra and the upper part of the hypocentra; the hypocentra pleuralia represent the remnants of the suppressed upper part of the bone.

Further change in the same direction leads to the structure found in the Triassic types, where the basioccipital and basisphenoid are extremely reduced, and the pterygoids are supported by the huge parasphenoid with which they are sometimes united by suture. The interpterygoid varieties are very large. In the vertebral column the intercentra seem to have been enlarged at the expense of the pleurocentra forming the so-called centrum of the stereospondylus vertebra, but much further work is necessary on this point.

In conclusion, taken as a whole the rachitomous Amphibia are intermediate in their structure, as they are in time, between the embolomerous and the stereospondylous types, and it seems that each of the three groups is to be regarded as ancestral to that which follows it.

The almost absolute identity of the skulls of *Pteroplax,* an embolomerous amphibian of Carboniferous type, and *Seymouvia,* which has the most primitive skull of any known reptile, seems to show definitely that the reptiles did arrive from that group of Amphibia, presumably in early Carboniferous or Upper Devonian time.

The suggestion may be made that the development of the bicondylar articulation of the skull of Amphibia is to be correlated with increasing depression of the skull, and is a characteristic amphibian feature.

5. *Note on the Skull and Teeth of Tursiops.*
By Professor R. J. ANDERSON, *M.D., F.L.S.*

The teeth present some characters which are not usually found in Cetacea. The number of teeth amounted to 90, but several were absent, owing to injury of the lower jaw. Of the teeth now under observation, three are but little worn —each is 3·5 cms. in length—and were perhaps about 4 cms. when unworn. The

fangs are rough and truncated, the crowns of two worn down at the sides for some distance; this looks as if the teeth were used for crushing. These teeth are not perfectly straight; two are slightly S-shaped. The smallest teeth are 2 cm. in length. In the lot I examined there are six; of these, four have small diameters, and two are wide and short, with thick fangs and a tendency to form two or three roots in one case. A small hole is present in the crown of the broadest and shortest tooth, but in the other short ones it does not appear. In another select group 2·2 cm. is the height. The crowns are not worn down enough to show the cavity; one of the teeth is bulged out at the lower part of the fang, as if a new root were attempted. One of the next group shows the central foramen in the crown distinctly, and two others imperfectly. The lengths are 1·3 cm. Another group, six in number, have a length of 2·5 cms.; none are perforate above. The sockets for the individual teeth appear at the bottom of the groove; the partitions do not reach the upper edge of the jaw. The lower jaw is 45 cms. long, with a height of 11 cms. behind condyle. The condyle is 4 cms. from lower border, and 5 cms. from upper edge. There are 25 sockets on each side in upper jaw, and 20 on each side in lower jaw. The antero-posterior of the left nasal is more than half the corresponding diameter of the right. The length of the skull is 21 inches, breadth 10 inches, and height 21 cms. The right premaxilla 41 cms., left 38·5 cms. The lower border of nares to the tip of the rostrum 36 cms. The skull is less symmetrical than that of Delphinapterus, and the shape is intermediate between that of Delphis Delphinapterus and Grampus. Professor Anthony has found stones in the second stomach of Phocæna. The green stuff sometimes found in the stomach of Tursiops may be accidentally swallowed with shore fish.

TABLE.—*Length of Teeth.*

6 teeth	2 cms.	1 tooth 2·4 cms.
3 teeth	2·2 cms.	3 teeth 2·5 cms.
6 teeth	2·3 cms.	1 tooth 3·4 cms.[1]
1 tooth	2·35 cms.	1 tooth 3·5 cms.[2]
		1 tooth 4·1 cms.[3]

Two of the short teeth are broad; one of these has a broad fang imperfectly divided.

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6. *Some Notes on the Skeletal Elements of the Mammalian Limb.* *By* Professor R. J. ANDERSON, *M.D., F.L.S.*

The condition of the elements of the mammalian limb is commonly associated with that of other vertebrate groups that have a manus and pes developed. It is easier to explain the structure of the fish limbs by referring to the archetype skeleton than to explain the structure of other vertebrate types in this way. The wings of birds may be referred, however, to a modified variety of the archetype skeleton. Whatever views we adopt, it can scarcely be advisable to undervalue the main factors in the production of the foci of relative rest and in the maintenance of periodic activity. These are as much in evidence in fishes and more easily understood than in the higher vertebrates. If specimens of wood are cut so as to form long, thin, and moderately wide bars, and if Lycopodium spores be shaken over the surfaces of these boards, tapping can be made to produce vibrations that will throw the powder into nodes and internodes not unlike the skeletal parts of the vertebrate limb. Muscle thrills associated with movement and neuro-muscular actions become consciously or unconsciously associated with aspirations of the central or other neurones. It seems clear that the limbs of selachians, sea lizards, and cetacea give us favourable illustrations of the results of the primitive attempts of movement by limbs and fins. Birds are somewhat removed from the accomplishments of these groups, but the feathers represent facts that accomplish for the wings and tail similar results in a medium where local vortices are made to help in the locomotion. Mammals

[1] Cut down at side for 0.6 cm. [2] Cut down at side for 1 cm.
[3] Bevelled at crown.

seem at first to have adopted a simpler plan, that comes somewhat within the domain of the working physicist. The adoption of different means of movement has led to complication. The use of the third and fourth toe in progressing, of the fourth especially in such forms as galago and other lemurs, and the special changes in the wrist and ankle bones have led to changes in the form, length, and strength of bones. The weight of the animal has often been a potent factor in modifying bone and limb. The relative thickness of the humerus and femur at the narrowest parts in mammals shows how much the weight of the animal or its parts and the activity of muscles avail in accomplishing work. The same holds with reference to certain other heavy headed varieties of ungulates. Thus the humerus of the elephant is of greater girth than that of the femur. It has less girth in the horse, and the girth is about equal in some breeds of domestic cattle. The forearm and the leg bones follow the same rule.

The smallest circumference of the humerus and femur are for the following animals measured :—

—	Giraffe	Cervus Capreolus	Equus Caballus	Equus Asinus	Camelus Dromedarius
Humerus .	14	4·0 cm.	13·3	8·6	17·0 cm.
Femur	14·5	4·5 cm.	6·7	10·0	14·5 cm.
—	Elephant	Rhinoceros	Irish Elk	Hippo-potamus	Bos
Humerus	23·5	25·2	17·5	20	11·2 cms.
Femur .	22·0	25·2	16·5	21	11·2 cms.

It becomes a question also with reference to the modulus of elasticity of the bone, and the modulus of firmness in each case, and also with reference to the size of the medullary canal.

The circumference of the humerus exceeds the least circumference of the femur in two buffaloes in the Museum d'Histoire Naturelle, Paris.

7. *The Solutré Type of Horse* (E. robustus) *in Prehistoric Britain. By* A. Irving, *D.Sc., B.A.*

A.—*Evidence from Teeth.*

1. In the excavation of a watermain trench (3¾ to 4 feet deep) across the Stort Valley in 1912[1] four teeth of the cheek-dentition have been found identified by their shape and by the antero-posterior lengths of their crowns and internal pillars respectively) with p.m. 2, p.m. 3, p.m. 4, and m. 3 of the series figured by Prof. J. C. Ewart, F.R.S., as of the Solutré type of horse (*E. robustus*) in his monograph on 'The Restoration of an Ancient British Race of Horses.'[2] To these may be added a p.m. 4 (Pleistocene) in the Sedgwick Museum (Cambridge), and the p.m. 4 from Piltdown,[3] recorded by Woodward and Dawson. Others have been identified in the museums of Saffron Walden and Maidstone.

2. A broken premaxilla retaining four large incisors corresponding by measurements with that of a 'forest' horse from Walthamstow in the British Museum (Nat. Hist.).

3. A p.m. 3 (identified by Prof. Ewart as of *E. robustus*[4]) found some years ago under 12 feet of Pleistocene gravel at Stanstead Abbots in the Lea Valley.

Of the above (1) and (2) were all found at the bottom of the 'rubble-drift' on the old land-surface of interglacial sands and Woolwich and Reading Beds, which were cut into in the trench.

[1] See *Herts and Essex Observer* (Mardon, Bishop's Stortford), for Feb. 8, 1913.
[2] *Proc. R. Soc. Edin.*, Session 1909-10 (fig. 23).
[3] *Q.J.G.S.*, vol. 69, p. 143; identified later.
[4] Now in the St. Albans Museum.

B.—*Evidence from Limb-bones.*

Metacarpals.—Prof. Ewart remarks in his paper 'On the Origin of Clydesdales, &c.' [1]: 'Many of the horses which inhabited central Europe in Pleistocene times had short broad cannon-bones. In the case of the 12- to 13-hands horses so abundant during the Solutréan Age to the north of Lyons the length of the metacarpal was as a rule about six times the width.'

A metacarpal from beneath the rubble-drift on the valley-flank (watermain trench) gives index=6; another from a similar position near the river gives index=5·83; a third found at a depth of 13 feet in the G.E.R. ballast-pits at Ponder's End gives index=6. Four others (Pleistocene) in the Sedgwick Museum give approximately the same index, agreeing (as a series) with five metacarpals in the Paris Museum (Ewart).

Other limb-bones found under the rubble-drift in the watermain trench :—

1. Two fragments of *radius* (wrist end); greatest width 93 mm., as against 85 mm. in the Stortford Skeleton.
2. Two distal portions of *humerus*; greatest width 92 mm., as against 81 mm. of the Skeleton.
3. A fragment of *humerus*; greatest width 91 mm., as against 87 mm. of the Skeleton at the 'external tubercle' (McFadyean).

(Specimens and lantern-slides at the Sectional Meeting).

The above facts, it is submitted, lead fairly to the conclusion that in later Pleistocene times horses of the Solutré type (as figured by the cavemen) roamed as far north as Southern Britain. Reference to a paper communicated to Section H at this Meeting, on later finds of the remains of horse of the Stortford-Grimaldi type.[2]

Remains of *Bos, Cervus elaphus, Ovis,* and *Sus* have also been found under similar conditions.

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8. *The Migration of Birds over Birmingham and the Midland District. By* F. COBURN.

[1] *Trans. Highland and Agri. Soc. of Scotland* (1911).

[2] See also *B. A. Reports,* Portsmouth Meeting (1911), p. 251.

Section E.—GEOGRAPHY.

President of the Section.—Professor H. N. Dickson, D.Sc.

THURSDAY, SEPTEMBER 11.

The President delivered the following Address :—

Since the last meeting of this Section the tragic fate of Captain Scott's party, after its successful journey to the South Pole, has become known; and our hopes of welcoming a great leader, after great achievement, have been disappointed. There is no need to repeat here the narrative of events, or to dwell upon the lessons afforded by the skill, and resource, and heroic persistence, which endured to the end. All these have been, or will be, placed upon permanent record. But it is right that we should add our word of appreciation, and proffer our sympathy to those who have suffered loss. It is for us also to take note that this latest of the great Antarctic expeditions has not merely reached the Pole, as another has done, but has added, to an extent that few successful exploratory undertakings have ever been able to do, to the sum of scientific geographical knowledge. As the materials secured are worked out it will, I believe, become more and more apparent that few of the physical and biological sciences have not received contributions, and important contributions, of new facts; and also that problems concerning the distribution of the different groups of phenomena and their action and reaction upon one another—the problems which are specially within the domain of the geographer—have not merely been extended in their scope but have been helped to their solution.

The reaching of the two Poles of the earth brings to a close a long and brilliant chapter in the story of geographical exploration. There is still before us a vista of arduous research in geography, bewildering almost in its extent, in such a degree indeed that 'the scope of geography' is in itself a subject of perennial interest. But the days of great pioneer discoveries in topography are definitely drawn to their close. We know the size and shape of the earth, at least to a first approximation, and as the map fills up we know that there can be no new continents and no new oceans to discover, although all are still, in a sense, to conquer. Looking back, we find that the qualities of human enterprise and endurance have shown no change; we need no list of names to prove that they were alike in the days of the earliest explorations, of the discovery of the New World or of the sea route to India, of the 'Principall Navigations,' or of this final attainment of the Poles. The love of adventure and the gifts of courage and endurance have remained the same : the order of discovery has been determined rather by the play of imagination upon accumulated knowledge, suggesting new methods and developing appropriate inventions. Men have dared to do risky things with inadequate appliances, and in doing so have shown how the appliances may be improved and how new enterprises may become possible as well as old ones easier and safer. As we come to the end of these 'great explorations,' and are restricted more and more to investigations of a less striking sort, it is well to remember that in geography, as in all other sciences,

research continues to make as great demands as ever upon those same qualities, and that the same recognition is due to those who continue in patient labour.

When we look into the future of geographical study, it appears that for some time to come we shall still be largely dependent upon work similar to that of the pioneer type to which I have referred, the work of perfecting the geographer's principal weapon, the map. There are many parts of the world about which we can say little except that we know they exist; even the topographical map, or the material for making it, is wanting; and of only a few regions are there really adequate distributional maps of any kind. These matters have been brought before this Section and discussed very fully in recent years, so I need say no more about them, except perhaps to express the hope and belief that the production of topographical maps of difficult regions may soon be greatly facilitated and accelerated with the help of the new art of flying.

I wish to-day rather to ask your attention for a short time to a phase of pioneer exploration which has excited an increasing amount of interest in recent years. Civilised man is, or ought to be, beginning to realise that in reducing more and more of the available surface of the earth to what he considers a habitable condition he is making so much progress, and making it so rapidly, that the problem of finding suitable accommodation for his increasing numbers must become urgent in a few generations. We are getting into the position of the merchant whose trade is constantly expanding and who foresees that his premises will shortly be too small for him. In our case removal to more commodious premises elsewhere seems impossible—we are not likely to find a means of migrating to another planet—so we are driven to consider means of rebuilding on the old site, and so making the best of what we have, that our business may not suffer.

In the type of civilisation with which we are most familiar there are two fundamental elements—supplies of food energy, and supplies of mechanical energy. Since at present, partly because of geographical conditions, these do not necessarily (or even in general) occur together, there is a third essential factor, the line of transport. It may be of interest to glance, in the cursory manner which is possible upon such occasions, at some geographical points concerning each of these factors, and to hazard some speculations as to the probable course of events in the future.

In his Presidential Address to the British Association at its meeting at Bristol in 1898, Sir William Crookes gave some valuable estimates of the world's supply of wheat, which, as he pointed out, is 'the most sustaining food-grain of the great Caucasian race.' Founding upon these estimates, he made a forecast of the relations between the probable rates of increase of supply and demand, and concluded that 'Should all the wheat-growing countries add to their (producing) area to the utmost capacity, on the most careful calculation the yield would give us only an addition of some 100,000,000 acres, supplying, at the average world-yield of 12·7 bushels to the acre, 1,270,000,000 bushels, just enough to supply the increase of population among bread-eaters till the year 1931.' The President then added, 'Thirty years is but a day in the life of a nation. Those present who may attend the meeting of the British Association thirty years hence will judge how far my forecasts are justified.'

Half the allotted span has now elapsed, and it may be useful to inquire how things are going. Fortunately this can be easily done, up to a certain point at any rate, by reference to a paper published recently by Dr. J. F. Unstead,[1] in which comparisons are given for the decades 1881-90, 1891-1900, and 1901-10. Dr. Unstead shows that the total wheat harvest for the world may be estimated at 2,258 million bushels for the first of these periods, 2,575 million for the second, and 3,233 million for the third, increases of 14 per cent. and 25 per cent. respectively. He points out that the increases were due 'mainly to an increased acreage,' the areas being 192, 211, and 242 million acres, but also 'to some extent (about 8 per cent.) to an increased average yield per acre, for while in the first two periods this was 12 bushels, in the third period it rose to 13 bushels per acre.'

If we take the period 1891-1900, as nearly corresponding to Sir William Crookes' initial date, we find that the succeeding period shows an increase of

[1] *Geographical Journal*, August 1913.

658 million bushels, or about half the estimated increase required by 1931, and that attained chiefly by 'increased acreage.'

But signs are not wanting that increase in this way will not go on indefinitely. We note (also from Dr. Unstead's paper) that in the two later periods the percentage of total wheat produced which was exported from the United States fell from 32 to 19, the yield per acre showing an increase meanwhile to 14 bushels. In the Russian Empire the percentage fell from 26 to 23, and only in the youngest of the new countries—Canada, Australia, the Argentine—do we find large proportional increases. Again, it is significant that in the United Kingdom, which is, and always has been, the most sensitive of all wheat-producing countries to variations in the floating supply, the *rate* of falling-off of home production shows marked if irregular diminution.

Looking at it in another way, we find (still from Dr. Unstead's figures) that the total amount sent out by the great exporting countries averaged, in 1881-90 295 million bushels, 1891-1900 402 millions, 1901-10 532 millions. These quantities represent respectively 13·0, 15·6, and 16·1 per cent. of the total production, and it would appear that the percentage available for export from these regions is, for the time at least, approaching its limit; *i.e.* that only about one-sixth of the wheat produced is available from surpluses in the regions of production for making good deficiencies elsewhere.

There is, on the other hand, abundant evidence that improved agriculture is beginning to raise the yield per acre over a large part of the producing area. Between the periods 1881-90 and 1901-10 the average in the United States rose from 12 to 14 bushels; in Russia from 8 to 10; in Australia from 8 to 10. It is likely that, in these last two cases at least, a part of the increase is due merely to more active occupation of fresh lands as well as to use of more suitable varieties of seed, and the effect of improvements in methods of cultivation alone is more apparent in the older countries. During the same period the average yield increased in the United Kingdom from 28 to 32 bushels, in France from 17 to 20, Holland 27 to 33, Belgium 30 to 35, and it is most marked in the German Empire, for which the figures are 19 and 29.

In another important paper[1] Dr. Unstead has shown that the production of wheat in North America may still, in all likelihood, be very largely increased by merely increasing the area under cultivation, and the reasoning by which he justifies this conclusion certainly holds good over large districts elsewhere. It is of course impossible, in the present crude state of our knowledge of our own planet, to form any accurate estimate of the area which may, by the use of suitable seeds or otherwise, become available for extensive cultivation. But I think it is clear that the available proportion of the total supply from 'extensive' sources has reached, or almost reached, its maximum, and that we must depend more and more upon intensive farming, with its greater demands for labour.

The average total area under wheat is estimated by Dr. Unstead as 192 million acres for 1881-90, 211 million acres for 1891-1900, and 242 million acres for 1901-10. Making the guess, for we can make nothing better, that this area may be increased to 300 million acres, and that under ordinary agriculture the average yield may eventually be increased to 20 bushels over the whole, we get an average harvest of 6,000 million bushels of wheat. The average wheat-eater consumes, according to Sir William Crookes' figures, about four and a-half bushels per annum; but the amount tends to increase. It is as much (according to Dr. Unstead) as six bushels in the United Kingdom and eight bushels in France. Let us take the British figure, and it appears that on a liberal estimate the earth may in the end be able to feed permanently 1,000 million wheat-eaters. If prophecies based on population statistics are trustworthy the crisis will be upon us before the end of this century. After that we must either depend upon some substitute to reduce the consumption per head of the staple foodstuff, or we must take to intensive farming of the most strenuous sort, absorbing enormous quantities of labour and introducing, sooner or later, serious difficulties connected with plant-food. We leave the possibility of diminishing the rate of increase in the number of bread-eaters out of account for the moment.

[1] *Geographical Journal*, April and May 1912.

We gather, then, that the estimates formed in 1898 are in the main correct, and the wheat problem must become one of urgency at no distant date, although actual shortage of food is a long way off. What is of more immediate significance to the geographer is the element of change, of return to earlier conditions, which is emerging even at the present time. If we admit, as I think we must do, that the days of increase of extensive farming on new land are drawing to a close, then we admit that the assignment of special areas for the production of the food-supply of other distant areas is also coming to its end. The opening up of such areas, in which a sparse population produces food in quantities largely in excess of its own needs, has been the characteristic of our time, but it must give place to a more uniform distribution of things, tending always to the condition of a moderately dense population, more uniformly distributed over large areas, capable of providing the increased labour necessary for the higher type of cultivation, and self-supporting in respect of grain-food at least. We observe in passing that the colonial system of our time only became possible on the large scale with the invention of the steam-locomotive, and that the introduction of railway systems in the appropriate regions, and the first tapping of nearly all such regions on the globe, has taken less than a century.

Concentration in special areas of settlement, formerly chiefly effected for military reasons, has in modern times been determined more and more by the distribution of supplies of energy. The position of the manufacturing district is primarily determined by the supply of coal. Other forms of energy are, no doubt, available, but, as Sir William Ramsay showed in his Presidential Address at the Portsmouth meeting in 1911, we must in all probability look to coal as being the chief permanent source.

In the early days of manufacturing industries the main difficulties arose from defective land transport. The first growth of the industrial system, therefore, took place where sea transport was relatively easy; raw material produced in a region near a coast was carried to a coalfield also near a coast, just as in the times when military power was chiefly a matter of 'natural defences,' the centre of power and the food-producing colony had to be mutually accessible. Hence the Atlantic took the place of the Mediterranean, Great Britain eventually succeeded Rome, and eastern North America became the counterpart of Northern Africa. It is to this, perhaps more than to anything else, that we owe our tremendous start amongst the industrial nations, and we observe that we used it to provide less favoured nations with the means of improving their system of land transport, as well as actually to manufacture imported raw material and redistribute the products.

But there is, of course, this difference between the supply of foodstuff (or even military power) and mechanical energy, that in the case of coal at least it is necessary to live entirely upon capital; the storing up of energy in new coalfields goes on so slowly in comparison with our rate of expenditure that it may be altogether neglected. Now in this country we began to use coal on a large scale a little more than a century ago. Our present yearly consumption is of the order of 300 millions of tons, and it is computed[1] that at the present rate of increase 'the whole of our available supply will be exhausted in 170 years.' With regard to the rest of the world we cannot, from lack of *data*, make even the broad assumptions that were possible in the case of wheat supply, and for that and other reasons it is therefore impossible even to guess at the time which must elapse before a universal dearth of coal becomes imminent; it is perhaps sufficient to observe that to the best of our knowledge and belief one of the world's largest groups of coalfields (our own) is not likely to last three centuries in all.

Here again the present interest lies rather in the phases of change which are actually with us. During the first stages of the manufacturing period energy in any form was exceedingly difficult to transport, and this led to intense concentration. Coal was taken from the most accessible coalfield and used, as far as possible, on the spot. It was chiefly converted into mechanical energy by means of the steam-engine, an extremely wasteful apparatus in small units, and hence still further concentration; thus the steam-engine is respon-

[1] *General Report of the Royal Commission on Coal Supplies*, 1906.

sible in part for the factory system in its worst aspect. The less accessible coalfields were neglected. Also, the only other really available source of energy —water-power—remained unused, because the difficulties in the way of utilising movements of large quantities of water through small vertical distances (as in tidal movements) are enormous; the only easily applied source occurs where comparatively small quantities of water fall through considerable vertical distances, as in the case of waterfalls. But, arising from the geographical conditions, waterfalls (with rare exceptions such as Niagara) occur in the 'torrential' part of the typical river-course, perhaps far from the sea, almost certainly in a region too broken in surface to allow of easy communication or even of industrial settlement of any kind.

However accessible a coalfield may be to begin with, it sooner or later becomes inaccessible in another way, as the coal near the surface is exhausted and the workings get deeper. No doubt the evil day is postponed for a time by improvements in methods of mining—a sort of intensive cultivation—but as we can put nothing back the end must be the same, and successful competition with more remote but more superficial deposits becomes impossible. And every improvement in land transport favours the geographically less accessible coalfield.

From this point of view it is impossible to overestimate the importance of what is to all intents and purposes a new departure of the same order of magnitude as the discovery of the art of smelting iron with coal, or the invention of the steam-engine, or of the steam-locomotive. I mean the conversion of energy into electricity, and its transmission in that form (at small cost and with small loss) through great distances. First we have the immediately increased availability of the great sources of cheap power in waterfalls. The energy may be transmitted through comparatively small distances and converted into heat in the electric furnace, making it possible to smelt economically the most refractory ores, as those of aluminium, and converting such unlikely places as the coast of Norway or the West Highlands of Scotland into manufacturing districts. Or it may be transmitted through greater distances to regions producing quantities of raw materials, distributed there widespread to manufacturing centres, and re-converted into mechanical energy. The Plain of Lombardy produces raw materials in abundance, but Italy has no coal supply. The waterfalls of the Alps yield much energy, and this transmitted in the form of electricity, in some cases for great distances, is converting Northern Italy into one of the world's great industrial regions. Chisholm gives an estimate of a possible supply of power amounting to 3,000,000 horse-power, and says that of this about one-tenth was already being utilised in the year 1900.

But assuming again, with Sir William Ramsay, that coal must continue to be the chief source of energy, it is clear that the question of accessibility now wears an entirely different aspect. It is not altogether beyond reason to imagine that the necessity for mining, as such, might entirely disappear, the coal being burnt *in situ* and energy converted directly into electricity. In this way some coalfields might conceivably be exhausted to their last pound without serious increase in the cost of getting. But for the present it is enough to note that, however inaccessible any coalfield may be from supplies of raw material, it is only necessary to establish generating stations at the pit's mouth and transport the energy to where it can be used. One may imagine, for example, vast manufactures carried on in what are now the immense agricultural regions of China, worked by power supplied from the great coal deposits of Shan-si.

There is, however, another peculiarity of electrical power which will exercise increasing influence upon the geographical distribution of industries. The small electric motor is a much more efficient apparatus than the small steam-engine. We are, accordingly, already becoming familiar with the great factory in which, instead of all tools being huddled together to save loss through shafting and belting, and all kept running all the time, whether busy or not (because the main engine must be run), each tool stands by itself and is worked by its own motor, and that only when it is wanted. Another of the causes of concentration of manufacturing industry is therefore reduced in importance. We may expect to see the effects of this becoming more and more

marked as time goes on, and other forces working towards uniform distribution make themselves more felt.

The points to be emphasised so far, then, are, first, that the time when the available areas whence food supply as represented by wheat is derived are likely to be taxed to their full capacity within a period of about the same length as that during which the modern colonial system has been developing in the past; secondly, that cheap supplies of energy may continue for a longer time, although eventually they must greatly diminish; and, thirdly, there must begin in the near future a great equalisation in the distribution of population. This equalisation must arise from a number of causes. More intensive cultivation will increase the amount of labour required in agriculture, and there will be less difference in the cost of production and yield due to differences of soil and climate. Manufacturing industries will be more uniformly distributed, because energy, obtained from a larger number of sources in the less accessible places, will be distributed over an increased number of centres. The distinction between agricultural and industrial regions will tend to become less and less clearly marked, and will eventually almost disappear in many parts of the world.

The effect of this upon the third element is of first-rate importance. It is clear that as the process of equalisation goes on the relative amount of long-distance transport will diminish, for each district will tend more and more to produce its own supply of staple food and carry on its own principal manufactures. This result will naturally be most marked in what we may call the 'east-and-west' transport, for as climatic controls primarily follow the parallels of latitude, the great *quantitative* trade, the flow of foodstuffs and manufactured articles to and fro between peoples of like habits and modes of life, runs primarily east and west. Thus the transcontinental functions of the great North American and Eurasian railways, the east-and-west systems of the inland waterways of the two continents, and the connecting-links furnished by the great ocean ferries, must become of relatively less importance.

The various stages may be represented, perhaps, in some such manner as this. If I is the cost of producing a thing locally at a place A by intensive cultivation or what corresponds to it, if E is the cost of producing the same thing at a distant place B, and T the cost of transporting it to A, then at A we may at some point of time have a more or less close approximation to

$$I = E + T.$$

We have seen that in this country, for example, I has been greater than $E + T$ for wheat ever since, say, the introduction of railways in North America, that the excess tends steadily to diminish, and that, however much it may be possible to reduce T either by devising cheaper modes of transport or by shortening the distance through which wheat is transported, $E + T$ must become greater than I, and it will pay us to grow all or most of our own wheat. Conversely, in the seventies of last century I was greater than $E + T$ in North America and Germany for such things as steel rails and rolling-stock, which we in this country were cultivating 'extensively' at the time on more accessible coalfields, with more skilled labour and better organisation than could be found elsewhere. In many cases the positions are now, as we know, reversed, but geographically I must win all round in the long run.

In the case of transport between points in different latitudes the conditions are, of course, altogether dissimilar, for in this case commodities consist of foodstuffs, or raw materials, or manufactured articles, which may be termed luxuries, in the sense that their use is scarcely known until cheap transport makes them easily accessible, when they rapidly become 'necessaries of life.' Of these the most familiar examples are tea, coffee, cocoa and bananas, india-rubber, and manufactured cotton goods. There is here, of course, always the possibility that wheat as a staple might be replaced by a foodstuff produced in the tropics, and it would be extremely interesting to study the geographical consequences of such an event as one-half of the surface of the earth suddenly coming to help in feeding the two quarters on either side; but for many reasons, which I need not go into here, such a consummation is exceedingly unlikely. What seems more probable is that the trade between different

latitudes will continue to be characterised specially by its variety, the variety doubtless increasing, and the quantity increasing in still larger measure. The chief modification in the future may perhaps be looked for in the occasional transference of manufactures of raw materials produced in the tropics to places within the tropics, especially when the manufactured article is itself largely consumed near regions of production. The necessary condition here is a region, such as (*e.g.*) the monsoon region, in which there is sufficient variation in the seasons to make the native population laborious; for then, and apparently only then, is it possible to secure sufficient industry and skill by training, and therefore to be able to yield to the ever-growing pressure in more temperate latitudes due to increased cost of labour. The best examples of this to-day are probably the familiar ones of cotton and jute manufacture in India. With certain limitations, manufacturing trade of this kind is, however, likely to continue between temperate and strictly tropical regions, where the climate is so uniform throughout the year that the native has no incentive to work. There the collection of the raw material is as much as, or even more than can be looked for—as in the case of mahogany or wild rubber. Where raw material has to be cultivated—as cotton, cultivated rubber, &c.—the raw material has to be produced in regions more of the monsoon type, but it will probably—perhaps as much for economic as geographical reasons—be manufactured at some centre in the temperate zones, and the finished product transported thence, when necessary, to the point of consumption in the tropics.

We are here, however, specially liable to grave disturbances of distribution arising from invention of new machinery or new chemical methods; one need only mention the production of sugar or indigo. Another aspect of this which is not without importance may perhaps be referred to here, although it means the transference of certain industries to more accessible regions merely, rather than a definite change of such an element as latitude. I have in mind the sudden conversion of an industry in which much labour is expended on a small amount of raw material into one where much raw material is consumed, and by the application of power-driven machinery the labour required is greatly diminished. One remembers when a fifty-shilling Swiss watch, although then still by tradition regarded as sufficiently valuable to deserve enclosure in a case constructed of a precious metal, was considered a marvel of cheapness. American machine-made watches, produced by the ton, are now encased in the baser metals and sold at some five shillings each, and the watch-making industry has ceased to be specially suited to mountainous districts.

In considering the differences which seem likely to arise in what we may call the regional pressures of one kind and another, pressures which are relieved or adjusted by and along certain lines of transport, I have made a primary distinction between 'east-and-west' and 'north-and-south' types, because both in matters of food-supply and in the modes of life which control the nature of the demand for manufactured articles climate is eventually the dominant factor; and, as I have said, climate varies primarily with latitude. This is true specially of atmospheric temperature; but temperature varies also with altitude, or height above the level of the sea. To a less extent rainfall, the other great element of climate, varies with latitude, but the variation is much more irregular. More important in this case is the influence of the distribution of land and sea, and more especially the configuration of the land surface, the tendency here being sometimes to strengthen the latitude effect where a continuous ridge is interposed, as in Asia, practically cutting off 'north-and-south' communication altogether along a certain line, emphasising the parallel-strip arrangement running east and west to the north of the line, and inducing the quite special conditions of the monsoon region to the south of it. We may contrast this with the effect of a 'north-and-south' structure, which (in temperate latitudes especially) tends to swing what we may call the regional lines round till they cross the parallels of latitude obliquely. This is typically illustrated in North America, where the angle is locally sometimes nearly a right angle. It follows, therefore, that the contrast of 'east-and-west' and 'north-and-south' lines, which I have here used for purposes of illustration, is necessarily extremely crude, and one of the most pressing duties of geographers at the present moment is to elaborate a more satisfactory method of classification. I am very glad that we are to have a discussion on 'Natural Regions' at

one of our sederunts. Perhaps I may be permitted to express the hope that we shall concern ourselves with the types of region we want, their structure or 'grain,' and their relative positions, rather than with the precise delimitation of their boundaries, to which I think we have sometimes been inclined, for educational purposes, to give a little too much attention.

Before leaving this I should like to add, speaking still in terms of 'east-and-west' and 'north-and-south,' one word more about the essential east-and-west structure of the Old World. I have already referred to the great central axis of Asia. This axis is prolonged westward through Europe, but it is cut through and broken to such an extent that we may include the Mediterranean region with the area lying further north, to which indeed it geographically belongs in any discussion of this sort. But the Mediterranean region is bounded on the other side by the Sahara, and none of our modern inventions facilitating transport has made any impression upon the dry desert; nor does it seem likely that such a desert will ever become a less formidable barrier than a great mountain mass or range. We may conclude, then, that in so far as the Old World is concerned the 'north-and-south' transport can never be carried on as freely as it may in the New, but only through certain weak points, or 'round the ends,' *i.e.* by sea. It may be further pointed out that the land areas in the southern hemisphere are so narrow that they will scarcely enter into the 'east-and-west' category at all—the transcontinental railway as understood in the northern hemisphere cannot exist; it is scarcely a pioneer system, but rather comes into existence as a later by-product of local east-and-west lines, as in Africa.

These geographical facts must exercise a profound influence upon the future of the British Isles. Trade south of the great dividing line must always be to a large extent of the 'north-and-south' type, and the British Isles stand practically at the western end of the great natural barrier. From their position the British Isles will always be a centre of immense importance in *entrepôt* trade, importing commodities from 'south' and distributing 'east and west,' and similarly in the reverse direction. This movement will be permanent, and will increase in volume long after the present type of purely 'east-and-west' trade has become relatively less important than it is now, and long after the British Isles have ceased to have any of the special advantages for manufacturing industries which are due to their own resources either in the way of energy or of raw material. We can well imagine, however, that this permanent advantage of position will react favourably, if indirectly, upon certain types of our manufactures, at least for a very long time to come.

Reverting briefly to the equalisation of the distribution of population in the wheat-producing areas and the causes which are now at work in this direction, it is interesting to inquire how geographical conditions are likely to influence this on the smaller scale. We may suppose that the production of staple foodstuffs must always be more uniformly distributed than the manufacture of raw materials, or the production of the raw materials themselves, for the most important raw materials of vegetable origin (as cotton, rubber, &c.) demand special climatic conditions, and, apart from the distribution of energy, manufacturing industries are strongly influenced by the distribution of mineral deposits, providing metals for machinery, and so on. It may, however, be remarked that the useful metals, such as iron, are widely distributed in or near regions which are not as a rule unfavourable to agriculture. Nevertheless, the fact remains that while a more uniform distribution is necessary and inevitable in the case of agriculture, many of the conditions of industrial and social life are in favour of concentration; the electrical transmission of energy removes, in whole or in part, only one or two of the centripetal forces. The general result might be an approximation to the conditions occurring in many parts of the monsoon areas—a number of fairly large towns pretty evenly distributed over a given agricultural area, and each drawing its main food supplies from the region surrounding it. The positions of such towns would be determined much more by industrial conditions, and less by military conditions, than in the past (military power being in these days mobile, and not fixed); but the result would on a larger scale be of the same type as was developed in the central counties of England, which, as Mackinder has pointed out, are of almost equal size and take the name of the county town. Concentration within the towns would, of course, be less severe than in the early days of

manufacturing industry. Each town would require a very elaborate and highly organised system of local transport, touching all points of its agricultural area, in addition to lines of communication with other towns and with the great 'north-and-south' lines of world-wide commerce, but these outside lines would be relatively of less importance than they are now. We note that the more perfect the system of local transport the less the need for points of intermediate exchange. The village and the local market-town will be 'sleepy' or decadent as they are now, but for a different reason; the symptoms are at present visible mainly because the country round about such local centres is overwhelmed by the great lines of transport which pass through them; they will survive for a time through inertia and the ease of foreign investment of capital. The effect of this influence is already apparent since the advent of the 'commercial motor,' but up to the present it has been more in the direction of distributing from the towns than collecting to them, producing a kind of 'suburbanisation' which throws things still further out of balance. The importance of the road motor in relation to the future development of the food-producing area is incalculable. It has long been clear that the railway of the type required for the great through lines of fast transport is ill-adapted for the detailed work of a small district, and the 'light' railway solves little and introduces many complications. The problem of determining the direction and capacity of a system of roads adequate to any particular region is at this stage one of extraordinary difficulty; experiments are exceedingly costly, and we have as yet little experience of a satisfactory kind to guide us. The geographer, if he will, can here be of considerable service to the engineer.

In the same connection, the development of the agricultural area supplying an industrial centre offers many difficult problems in relation to what may be called accessory products, more especially those of a perishable nature, such as meat and milk. In the case of meat the present position is that much land which may eventually become available for grain crops is used for grazing, or cattle are fed on some grain, like maize, which is difficult to transport or is not satisfactory for bread-making. The meat is then temporarily deprived of its perishable property by refrigeration, and does not suffer in transport Modern refrigerating machinery is elaborate and complicated, and more suited to use on board ship than on any kind of land transport. Hence the most convenient regions for producing meat for export are those near the sea-coast, such as occur in the Argentine or the Canterbury plains of New Zealand. The case is similar to that of the 'accessible' coalfield. Possibly the preserving processes may be simplified and cheapened, making overland transport easier, but the fact that it usually takes a good deal of land to produce a comparatively small quantity of meat will make the difficulty greater as land becomes more valuable. Cow's milk, which in modern times has become a 'necessary of life' in most parts of the civilised world, is in much the same category as meat, except that difficulties of preservation, and therefore of transport, are even greater. That the problem has not become acute is largely due to the growth of the long-transport system available for wheat, which has enabled land round the great centres of population to be devoted to dairy produce. If we are right in supposing that this state of things cannot be permanent the difficulty of milk supply must increase, although relieved somewhat by the less intense concentration in the towns; unless, as seems not unlikely, a wholly successful method of permanent preservation is devised.

In determining the positions of the main centres, or rather, in subdividing the larger areas for the distribution of towns with their supporting and dependent districts, water supply must be one of the chief factors in the future, as it has been in the past; and in the case of industrial centres the quality as well as the quantity of water has to be considered. A fundamental division here would probably be into districts having a natural local supply, probably of hard water, and districts in which the supply must be obtained from a distance. In the latter case engineering works of great magnitude must often be involved. and the question of total resources available in one district for the supply of another must be much more fully investigated than it has been. In many cases, as in this country, the protection of such resources pending investigation is already much needed. It is worth noting that the question may often be closely related to the development and transmission of electrical energy from waterfalls,

and the two problems might in such cases be dealt with together. Much may be learned about the relation of water supply to distribution of population from a study of history, and a more active prosecution of combined historical and geographical research would, I believe, furnish useful material in this connection, besides throwing interesting light on many historical questions.

Continued exchange of the 'north-and-south' type and at least a part of that described as 'east-and-west' gives permanence to a certain number of points where, so far as can be seen, there must always be a change in the mode of transport. It is not likely that we shall have heavy freight-carrying monsters in the air for a long time to come, and until we have the aerial 'tramp' transport must be effected on the surfaces of land and sea. However much we may improve and cheapen land transport it cannot in the nature of things become as cheap as transport by sea. For on land the essential idea is always that of a prepared road of some kind, and, as Chisholm has pointed out, no road can carry more than a certain amount; traffic beyond a certain quantity constantly requires the construction of new roads. It follows, then, that no device is likely to provide transport indifferently over land and sea, and the seaport has in consequence inherent elements of permanence. Improved and cheapened land transport increases the economy arising from the employment of large ships rather than small ones, for not only does transport inland become relatively more important, but distribution along a coast from one large seaport becomes as easy as from a number of small coastal towns. Hence the conditions are in favour of the growth of a comparatively small number of immense seaport cities like London and New York, in which there must be great concentration not merely of work directly connected with shipping, but of commercial and financial interests of all sorts. The seaport is, in fact, the type of great city which seems likely to increase continually in size, and provision for its needs cannot in general be made from the region immediately surrounding it, as in the case of towns of other kinds. In special cases there is also, no doubt, permanent need of large inland centres of the type of the 'railway creation,' but under severe geographic control these must depend very much on the nature and efficiency of the systems of land transport. It is not too much to say (for we possess some evidence of it already) that the number of distinct geographical causes which give rise to the establishment and maintenance of individual great cities is steadily diminishing, but that the large seaport is a permanent and increasing necessity. It follows that aggregations of the type of London and Liverpool, Glasgow and Belfast will always be amongst the chief things to be reckoned with in these islands, irrespective of local coal supply or accessory manufacturing industries, which may decay through exhaustion.

I have attempted in what precedes to draw attention once more to certain matters for which it seems strangely difficult to get a hearing. What it amounts to is this, that as far as our information goes the development of the steamship and the railway, and the universal introduction of machinery which has arisen from it, have so increased the demand made by man upon the earth's resources that in less than a century they will have become fully taxed. When colonisation and settlement in a new country proceeded slowly and laboriously, extending centrifugally from one or two favourable spots on the coast, it took a matter of four centuries to open up a region the size of England. Now we do as much for a continent like North America in about as many decades. In the first case it was not worth troubling about the exhaustion of resources, for they were scarcely more than touched, and even if they were exhausted there were other whole continents to conquer. But now, so far as our information goes, we are already making serious inroads upon the resources of the whole earth. One has no desire to sound an unduly alarmist note, or to suggest that we are in imminent danger of starvation, but surely it would be well, even on the suspicion, to see if our information is adequate and reliable and if our conclusions are correct; and not merely to drift in a manner which was justifiable enough in Saxon times, but which, at the rate things are going now, may land us unexpectedly in difficulties of appalling magnitude.

What is wanted is that we should seriously address ourselves to a stock-taking of our resources. A beginning has been made with a great map on the scale of one to a million, but that is not sufficient; we should vigorously proceed with the collection and discussion of geographical data of all kinds, so that

the major natural distributions shall be adequately known, and not merely those parts which commend themselves, for one reason or another, to special national or private enterprises. The method of Government survey employed in most civilised countries for the construction of maps, the examination of geological structure or the observation of weather and climate, is satisfactory as far as it goes, but it should go further, and be made to include such things as vegetation, water supply, supplies of energy of all kinds, and, what is quite as important, the bearings of one element upon others under different conditions. Much, if not most, of the work of collecting *data* would naturally be done as it is now by experts in the special branches of knowledge, but it is essential that there should be a definite plan of a *geographical* survey as a whole, in order that the regional or distributional aspect should never be lost sight of. I may venture to suggest that a committee formed jointly by the great national geographical societies, or by the International Geographical Congress, might be entrusted with the work of formulating some such uniform plan and suggesting practicable methods of carrying it out. It should not be impossible to secure international co-operation, for there is no need to investigate too closely the secrets of anyone's particular private vineyard—it is merely a question of doing thoroughly and systematically what is already done in some regions, sometimes thoroughly, but not systematically. We should thus arrive eventually at uniform methods of stock-taking, and the actual operations could be carried on as opportunity offered and indifference or opposition was overcome by the increasing need for information. Eventually we shall find that 'country-planning' will become as important as town-planning, but it will be a more complex business, and it will not be possible to get the facts together in a hurry. And in the meanwhile increased geographical knowledge will yield scientific results of much significance about such matters as distribution of populations and industries, and the degree of adjustment to new conditions which occurs or is possible in different regions and amongst different peoples. Primary surveys on the large scale are specially important in new regions, but the best methods of developing such areas and of adjusting distributions in old areas to new economic conditions are to be discovered by extending the detailed surveys of small districts. An example of how this may be done has been given by Dr. Mill in his 'Fragment of the Geography of Sussex.' Dr. Mill's methods have been successfully applied by individual investigators to other districts, but a definitely organised system, marked out on a carefully matured uniform plan, is necessary if the results are to be fully comparable. The schools of geography in this country have already done a good deal of local geography of this type, and could give much valuable assistance if the work were organised beforehand on an adequate scale.

But in whatever way and on whatever scale the work is done, it must be clearly understood that no partial study from the physical, or biological, or historical, or economic point of view will ever suffice. The urgent matters are questions of distribution upon the surface of the earth, and their elucidation is not the special business of the physicist, or the biologist, or the historian, or the economist, but of the geographer.

The following Papers and Reports were then read :—

1. *Completion of the Map of Prince Charles Foreland, Spitsbergen. By* W. S. Bruce, *LL.D., F.R.S.E.*

Dr. Bruce gave a further account of the charting of Prince Charles Foreland, Spitsbergen. He was able to report not only the completion of the survey, but also the publication of the map.

The work was conducted by Dr. Bruce and Mr. John Mathieson, F.R.S.G.S., of the Ordnance Survey (Scotland), assisted by Mr. J. V. Burn Murdoch, Dr. R. N. Rudmose Brown, Mr. E. A. Miller, Mr. Stewart Ross, the late Mr. Angus Peach, Mr. Alastair Geddes, Mr. Gilbert Kerr, Captain Napier, and Mr. Sword.

The field work was carried on during the summers of 1906, 1907, and 1909, and the office work in the intermediate periods and since 1909.

The chart was actually completed and sent to Paris in 1911, and has been published during the last few weeks.

The whole of the office work was carried out by Dr. Bruce and Mr. Mathieson, who accompanied Dr. Bruce in the field during the summer of 1909, while completing the survey of the southern extremity of the Foreland.

Mr. Mathieson was able to cross his work with that of Dr. Bruce, and the result has been highly satisfactory, in that the observations of the one surveyor have been checked by those of the other.

Besides the topographical survey of the Foreland, Dr. Bruce was able to take a number of soundings in Foreland Sound.

Owing to the inaccessibility of most of the mountain peaks the method adopted for the survey was to measure two base lines—one at the north end 12,000 feet, and another across the flat land at the south end 20,146 feet. These were measured by a Chesterman steel tape, and from their extremities a network of triangles was spread over the whole island. More than eighty summits were observed.

The coast line was surveyed by a measured traverse, which was connected with the triangulation at every available point. Fjords at the south end presented difficulties, where measurements had to be taken by the subtense method, and also along the 20 miles of crevassed glaciers on the east side, where trigonometrical points were fixed at suitable intervals, as actual measurements were out of the question.

Additional observations were also made from the mainland at three important stations in order to bring the Foreland into satisfactory relationship with the mainland.

The heights and horizontal angles were observed by 6-inch theodolites, and nearly all the altitudes were observed from at least two independent points. The Devil's Thumb was observed from more than fifteen points, and heights obtained varying from 2,590 feet to 2,610 feet, giving a mean of 2,602 feet. Similarly, Saddle Mount was observed from over twenty stations, and the heights obtained varied from 1,400 feet to 1,410 feet, giving a mean of 1,406 feet. This mountain was stated by early explorers to be 600 feet, but later it rose to 800 feet, then to 1,000 feet, and, latterly, to 1,200 feet.

The magnetic variation was 14° 40′ in 1909, and the dip 73° 23′. The latitude was observed in five different places, many observations being taken at most of the places.

The area of the island is about two hundred and fifty square miles, half of which is below the 100-feet contour, and one-fifth of which is covered by glaciers. The remainder consists of high mountain peaks and huge moraines.

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2. *Gaping Ghyll, Yorkshire: Its Exploration and Survey. By* C. A. Hill, *M.A., M.B.*

Gaping Ghyll, the best known of the Yorkshire pot-holes, is situated on the south-eastern flank of Ingleborough, the opening being about 1,350 feet above O.D. It consists of a vertical shaft in the limestone, 360 feet in depth, ending in a huge chamber from which passages extend for a distance of upwards of a mile. A stream, the Fell Beck, is engulfed in this chasm and reappears at Beck Head at a slightly lower level than the entrance to the famous Clapham Cave.

The first mention of Gaping Ghyll is found in Defoe's 'Tour of England,'[1] where it is called Gaper Gill. A partial descent of the hole was made in 1872 by Mr. Birkbeck, of Settle, who then ascertained its true depth. The first complete descent was achieved by M. Martel, of Paris, in August 1895, by means of rope ladders.[2]

In May 1896 the members of the Yorkshire Ramblers' Club made the second descent by means of a boatswain's chair lowered from a windlass. About a quarter of a mile of passages was surveyed on this occasion, and a plan and section afterwards published in the Club Journal.[3]

[1] Seventh edition. 1769, vol. iii., p. 293.
[2] Martel, *Irlande et Cavernes Anglaises*, 1897, chap. xxiv.
[3] *Y.R.C. Journal*, No. 2, Jan. 1900.

In 1903 the systematic exploration and survey were taken in hand and descents have since been made annually by the 'windlass' method. The total length of passages now known and surveyed amounts to about 2,050 yards.

A plan of the survey up to date will be found in the 'Yorkshire Ramblers' Club Journal,' No. 7, 1906-7, and a completed one is now in course of preparation and will shortly be published.

In addition to the work underground much valuable information has been obtained concerning the different channels by which the water of Fell Beck enters the Shaft and the Great Chamber. These channels have been studied by means of fluorescein and by actual exploration, and the completed plan is in course of publication.

By plotting out the underground survey on the moor above an interesting discovery was made in 1909 by the members of the Yorkshire Speleological Association, who were able by opening out a 'shake-hole' blocked by glacial drift to make their way finally into one of the underground passages of Gaping Ghyll otherwise than down the main shaft.[1]

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3. *Across Southern Jubaland from the Coast to Mount Kenia.* *By* I. N. Dracopoli.

The immediate object of this journey was to elucidate the hydrographical problems presented by the disappearance of the river Uaso Nyiro into the Lorian Swamp, and to map as much as possible of the unknown country lying between the latter place and the sea, which had not been previously visited by a white man.

A start was made from Kismayu, an Arab port situated some nine miles south of the mouth of the Juba River. Behind Kismayu, and parallel to the coast, lies a low range of sandhills covered with dense bush, above which stand out numerous conifers (*Juniperus procera*). The general slope of the land is from the north-west towards the south-east. The country consists of a series of broad, shallow valleys almost imperceptible to the eye, for the most part overgrown with dense bush and forest, and running in the same general direction. Down the centre of these valleys there are dry river-beds, mostly sandy and densely covered with jungle. As they draw near the sea these valleys and low, rounded ridges disappear, giving place in the north to a level arid plain, which is bounded on the east by the above-mentioned sandhills. In the south-east the country consists of a densely wooded plateau of slight elevation, drained by the rivers Durnford and Arnolé. Near the coast in the Biskayia district are several mangrove swamps infested with the tsetse fly. The main watershed in Southern Jubaland is that which divides the valley of the Lak Dera from that of the Guranlagga. The latter stream rises in the district of Kurde and flows almost due east, a very different course from that marked on existing maps There is an important swamp containing a large amount of water in the district of Gulola. The country in the interior alternates between impenetrable acacia scrub and open park-like glades, which afford admirable pasturage for cattle, goats, and sheep, but the districts of Rama Gudi and Arroga are arid in the extreme.

Southern Jubaland is inhabited by the Ogaden section of the Darod Somali, and by a fast-diminishing tribe called the Waboni, who live in a state of semi-slavery. The Galla, who originally inhabited the country, have been driven southwards and westwards by the victorious Somali. Of the latter, the most important sub-tribes are the Mohammed Zubheir, the Abd Wak, the Aulehan, the Abdulla, and the Maghábul, of which the latter are the only ones to profess friendship for the white man. Near the coast are found some Herti Somali. The wealth of the Somali consists of vast herds of camels, cattle, goats, and sheep, while they depend for food chiefly on milk and ghee. They are strict Mohammedans of the Shujai sect.

The Lorian district differs in many essential points from Southern Jubaland. The Uaso Nyiro River, which rises in the high tableland to the N.W. of Mount Kenia, attains its greatest development near the remarkable volcanic

[1] *Y.R.C. Journal*, No. 10, 1910.

plateau called Marti by the natives. It then gradually diminishes in volume, flowing slowly through gently sloping alluvial plains until, on entering the main Lorian swamp, it is scarcely thirty feet broad and two deep. This swamp is roughly oval in shape, with its long axis N.W. and S.E., and it is very roughly fifty miles in circumference. Much water is here lost by evaporation and percolation. The river, however, emerges in a still further attenuated form, and flows between high banks for five miles before entering a second and smaller swamp. On emerging once again, it gradually dwindles until permanent water ceases in a series of pools known to the natives as Madolé. There is, however, a distinct stream bed that runs in a shallow valley towards the east until Afmadu is reached, when it turns southwards, finally joining the Juba River by means of the Deshek Wama. In an exceptionally wet season the overflow from the Lorian Swamp runs down this stream bed, which is known as the Lak Dera, and into the sea, by way of the Juba River. The alluvial plains of the Lorian district are remarkably fertile, and are eminently suited for agriculture.

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4. *Report on Geographical Teaching in Scotland.* See Reports, p. 161.

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5. *Report on the Choice and Style of Atlas, Textual, and Wall Maps for School and University Use.*—See Reports, p. 156.

FRIDAY, SEPTEMBER 12.

The following Papers were read :—

1. *The Upper Basin of the Warwick Avon. By* Miss C. A. SIMPSON.

The Avon basin is part of the great valley crossing the Midlands from S.W. to N.E. at the foot of the Oolitic escarpment.

The Avon as a whole is a longitudinal river, but very few streams in its basin, above Warwick, are actually strike streams, though there is a line of detached valleys at the foot of the escarpment. The main streams flow obliquely across parallel outcrops of rock, ranging from Inferior Oolites in the S.E., through bands of Lias and Triassic marls, to an inlier of Permian sandstone, which is bounded on the N.E. by the Nuneaton coal-field.

The northern and western boundary of the Upper Avon basin crosses the uplands of this formation; and on the south the boundary follows the Oolitic escarpment. On the north-east is a very narrow water-parting between the Avon and the Welland—at a comparatively low level. Within the Avon basin, the two almost equally important valleys of the Upper Avon, and of the Leam continued by Rainsbrook Valley, have defined the plateau on which Rugby stands, and so have further dissected the Great Midland valley. Profiles of these two valleys, and of that of the Sowe-Avon, show complications of the drainage system, and suggest problems. Distribution of glacial drift and its possible influence on the streams. Its effect on the scenery. The soil is more dependent on distribution of drift than on the underlying rock. Positions of springs. The general character of the vegetation is very uniform throughout the district. Most arable land is near the Avon and Leam valleys between Rugby and Warwick, but meadows border the immediate banks of the streams, and pasture-land occurs almost exclusively on the borders of Leicestershire and Northamptonshire. Comparative scarcity of population in the Avon valley above Rugby. The density of population per 1,000 acres in each parish in the years 1801, 1841, 1881 and 1911 shows a general increase up to 1881; but on the whole, and especially during the later part of the period, the larger towns have increased, and the country districts have decreased, in population. Illustrated by the percentage of increase and decrease in each parish during the

periods 1801-1911 and 1881-1911. Different periods of greatest growth in Coventry, Leamington, and Rugby.

The Upper Avon basin is crossed by several important lines of communication, mainly from S.E. to N. or N.W. The Watling Street and the Fosse Way are no longer used as main roads, but, in addition to these, certain main roads cross the district. They run mainly across uplands, in contrast to the railways and canals, which often follow valleys.

2. *Notes on the Geography of Shropshire. By* Professor W. W. Watts, *F.R.S.*

3. *The Midland Plateau and its Influence on the English Settlement of Britain. By* P. E. Martineau.

The Midland Plateau lies between the Severn, Avon, and Trent. It is of oval form, and measures 46 miles from N.N.W. to S.S.E. by 34 from E.N.E. to W.S.W. It is nearly 130 miles in circuit and its area is almost exactly 1,000 square miles.

It is part of the Triassic plain of Middle England, and owes to a rim of hard rocks by which it is enclosed its resistance to denudation, and its consequent elevation above the general level of the plain. This rim has also the effect of making the plateau's frontier a steep escarpment, easily distinguishable on the map and in the field.

The river Tame on the north and the Stour and Alne-Arrow on the south have cut wide and deep valleys through weak parts of the rim, without destroying the continuity of the plateau. The Tame drains more than half the plateau, and to it the ground slopes gently inwards from all parts of the rim. The other streams named are marginal. Erosion by them has been rapid and the sides of their valleys are steep.

The outward escarpment is marked on the map by the 300-ft. and 400-ft. contour lines, which are close together. The 500-ft. line is generally close by, and the high ground of the plateau is disposed round its edge. This is especially the case on the southern side, where are found two points over 1,000 ft. and many of 900 and 800. Water-level in the Severn is 100 ft. at Bridgnorth Bridge, and the 100-ft. contour line comes up the Avon to within four miles of Stratford. The south edge of the plateau is thus not only steep but of considerable height, and is a serious obstacle to travel, as is shown by the Midland Railway's Blackwell bank of 1 in 37.5 and the Great Western's Old Hill bank of 1 in 50.

During the fifth and sixth centuries the English (or Anglo-Saxon) settlement of Britain was gradually completed, and the southern edge of the plateau marks the meeting of the two main waves of colonists, who may be described for convenience of reference as the Humber (or English) and the Southampton (or Saxon).

To some extent modern county boundaries follow the crest of the escarpment and preserve the ancient line of division, but they are often misleading and the older diocese frontier is a better guide. Best of all are parish and manorial boundaries, which not only mark the main tribal frontier, but also show separate outposts and defensible positions. Such outposts are Tardebigge, Clent, and Forshaw to the south, and Oldbury and Dudley to the north of the frontier line. Wherever there is a divergence from the rule that the crest of the escarpment is the frontier, geographical reason for that divergence can be adduced.

4. *The Growth of Birmingham. By* W. H. Foxall.

The early history of Birmingham is somewhat scantily recorded. Situated on the outskirts of Arden Forest, the hamlet lay considerably off the main Roman roads, but a connecting-link between the Watling Street and the southern part of the Fosse Way was in close proximity.

The determination of the town's position was due wholly to geographical

conditions, for peninsulas of high ground lay between the valleys of the Tame, the Rea, and the Cole, and in each valley there existed extensive and almost impassable marsh-land, which could only be crossed at certain well-defined points, and here ran the ancient ways which connected the towns of the north and west with those of the south and east.

The existence of Birmingham is recorded in Domesday Book, but it is seldom mentioned in the historical records of the country previous to the time of the Stuarts; yet during that period the place was growing in size and importance.

From the surrounding centres of population already established trackways converged upon this locality, which thus became a centre—a meeting-place for individuals and a market for the exchange of commodities. In the reign of Henry II. the lord of the manor secured rights to establish a market. Small as this was, compared with our present-day idea of a market, it was sufficient to give the place an advantage over other localities; for the possession of a favoured and established market not only attracted traders, but also necessitated the provision of accommodation for those traders and their wares. It was from such small beginnings that the trade, and, later, the local manufactures of the town developed. Practically every writer on old Birmingham refers to the town in this twofold aspect.

With the development of the coal and iron industry in South Staffordshire the business of Birmingham increased, for, from being the market town, it became also the distributing centre; so that the one expanded in proportion as the development of the other progressed.

The construction of canals which radiated from Birmingham, the improvements to the steam engine, followed later by the introduction of railways, gave an impetus to the town's manufactures and to the industries of the Black Country, and further established Birmingham as a trading and distributing centre.

The passing of Acts for the improvement of roads, buildings, markets, &c., in the early part of the nineteenth century marks the beginning of the transformation of Birmingham from an overgrown market-town into the chief Midland commercial centre.

Its later progress is due to the industrial skill and inventive genius of its inhabitants, and to that commercial enterprise which has recognised and utilised the advantages that depend on geographical situation.

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5. *The Black Country and its Borderland. By* H. Kay.

Five county boroughs and a score of smaller towns crowd the small area known as the Black Country, whilst Birmingham and its suburbs stand at its south-eastern corner. The population approaches 1,750,000, and is perhaps denser than that of any area of equal size outside London. The presence of so many people is due to the abundance of valuable minerals near the surface and to the industries which have arisen in consequence. Birmingham had initial advantages of situation, as, by reason of the swamp-bound rivers Tame and Rea, she stood at the natural meeting-place of all lines of communication between north-west and south-east. Her market, therefore, was the most accessible in the Midlands. Manufactures arose owing to the proximity of the Black Country, for whose productions Birmingham became the chief distributing centre. The city still retains the dual character thus impressed upon her.

The mineral wealth of the Black Country consisted of unrivalled stores of coal and of ironstone, together with limestone, fire-clay, and brick-clay. One seam of coal is ten yards thick. The mines of the central portion are now largely exhausted, or flooded by water, and fresh supplies are being developed east and west. Limestone is got from underground workings at Dudley, the Wren's Nest, and Walsall, and magnificent caverns have been excavated at these places. Fire-clay is obtained from the Stour Valley, and brick-clay is abundant everywhere.

Local place-names are chiefly of Saxon origin, and Saxon architecture is visible at St. Kenelm's Church near Clent. Dudley Castle possesses historical associations ranging from Saxon times to the Hanoverian period, and its ruins are most interesting. Norman architecture may be seen at Wolverhampton, in

the ruins of the twelfth-century Cluniac priory at Dudley, and in those of Halesowen Abbey (thirteenth century).

The Borderlands present a combination of rich and varied scenery with interesting historical, legendary, and literary associations. As typical instances may be mentioned the following: Tong, with rock dwellings, legends of Hengist, and memories of Charles Dickens' Little Nell; Boscobel and the Royal Oak; Holbeache and the Gunpowder Plot; Kinver with rock dwellings, legends, and charming scenery; Hagley, the Poets' Retreat beloved of Pope, Shenstone, and Thomson; Clent with its legends (sung by Chaucer and Milton) of St. Kenelm, the boy king of Mercia; Shakespeare's Country and the Forest of Arden; Kenilworth; Coventry; Tamworth; Lichfield; Sutton Coldfield and Barr Beacon; Wall (the Roman *Etocetum*); Cannock Chase; the Wrekin and *Uriconium*; and the incomparable Severn Valley.

MONDAY, SEPTEMBER 15.

The following Papers were read :—

1. *The Expansion of the Fjord Peoples and its Geographical Conditions. By* C. B. FAWCETT, *B.Litt.*, *B.Sc.*

The Fjordlands considered are Norway, the North-West Coast of North America, and Magallanes.

Each of these is a narrow and fragmentary strip of coast backed by barren highland, with only small and scattered patches of lowland. Their climates are all of the same type, wet, cool and equable, unfavourable to agriculture, but with open sea at all seasons. The peoples depend mainly on the sea for their food and means of communication, and therefore their expansion has been along the waterways.

Each fjord coast is on the mountainous western edge of a continent in high latitudes, but in other respects their positions are very different. Magallanes is at an end of the inhabited earth, with desert coasts to the north and a wide ocean on all other sides. The N.W. Coast is exposed to Asiatic and Polynesian influences, and is less completely shut off from its hinderland than the other fjordlands. The South of Norway borders the 'Narrow Seas,' and thence had communication with Europe and the Mediterranean.

In each of these lands there has been a mingling of races, but in each the uniformity of the local conditions and the separation from other peoples has made the inhabitants one people in their modes of life. Their relative social development has been mainly influenced by their skill in navigation. This directly determined the range and security of their food supply, and the growth of population and organisation, and therefore the power of expansion. The development of navigation was local, and limited, in Magallanes. On the N.W. Coast only dug-out vessels were employed. The Norse ships were influenced by those of Europe and the Mediterranean, and here navigation very early reached a high stage of development.

The expansion of the N.W. Amerinds was limited to the region bounded by the mountains and the ocean east and west and the desert and Arctic coasts south and north. The only practicable route was up the rivers; and that demanded a complete change in their mode of life. The limits to expansion from Magallanes were similar, but even narrower.

The Norsemen were not checked by any such barriers and they spread along three chief routes: (1) N.E. to Finmark and the White Sea, (2) westward to Iceland and Greenland, and (3) S.W. to the British Isles. The fourth route, to the S.E., was blocked by the Danes and Swedes. The form of the expansion in each case was determined by the social condition of the people visited, and the causes of the early success and later rapid decline of the Viking Power are to be found in the state of affairs in Norway and Western Europe at the time and the limited resources of Norway.

2. *The Physical Geography of the Entrance to Inverness Firth.* *By* A. G. Ogilvie.

3. *Spitsbergen Economically Considered.* *By* Dr. W. S. Bruce, *F.R.S.E.*

4. *On Australia.* *By* Professor J. W. Gregory, *F.R.S.*

Australia, the great island continent, owes its chief characteristics to its antiquity and its long isolation. It is essentially built of a series of plateaus, which form the Highlands of Eastern Australia and the great western plateau. They are united by wide lowland plains, which cross the continent from north to south. The western plateau has an even surface due to peneplanation in middle Kainozoic times, aided by wind action. The Eastern Highlands are more complex, as the plateau has been broken up by many sunklands and dissected by deep river gorges. The mountain system is independent of recent folding, and there are no fold mountains. The 'Cordillera' are dissected highlands, and are not comparable in structure to the chains of the Andes. The Eastern Highlands are bounded to the east by the fractures which lowered the former continuation of the land below the Pacific.

Owing to its continental size Australia has great diversity in character, and ranges from tropical to temperate. Its political geography is dominated by the contrast of the arid interior and the well watered coastlands.

Resources.—The development was first pastoral; its mineral wealth depends mainly on gold and coal, with some copper, lead, silver, tin, &c. Its main wealth now comes from its pastoral and agricultural industries and the industrial development dependent on them.

The aboriginal inhabitants are more akin to Caucasians than to Negroes or Mongols. Their numbers were always small, and they are of no serious political importance; they present no difficulty to the attainment of the ideal of a White Australia.

TUESDAY, SEPTEMBER 16.

Joint Meeting with Section A.

The following Papers were read :—

(i) *The Accuracy of the Principal Triangulation.* *By* Captain Winterbotham.

The Principal Triangulation of the United Kingdom was begun in 1783. Mean date of execution, 1825. Instruments used, 3-ft., 2-ft., and 18-inch Theodolites. Mean length of side, 35·4 miles. Probable error of an angle 1″23 $\left(\text{General Ferrero's formula } \sqrt{\frac{\Sigma v^2}{3n}} \times \cdot 6745\right)$.

The whole figure adjusted in 21 parts, of which 4 were independent.

Horizontal distances depend on a 'Mean Base,' got by applying corrections to the measured lengths of the two bases, Lough Foyle and Salisbury Plain, proportional to the square root of the lengths, in such a manner that the calculated length of each from the other agrees with the corrected measured length.

The mean probable error of an angle for all other national systems reported in the 1892 report of the International Geodetic Association (by General Ferrero) is 0″8.

Two factors omitted in General Ferrero's formula are the strength of the various figures and the mean lengths of the sides.

Judged purely by the probable error of an angle calculated from Ferrero's

formula, the Principal Triangulation of the United Kingdom appeared to be inferior in accuracy to the Continental systems. Various proposals for the remeasurement of the principal arcs were made, *e.g.*, at the 1906 and 1908 meetings of the British Association for the Advancement of Science at York and Dublin. In 1908 it was decided to remeasure a small portion of the Principal Triangulation remote from the bases in order to ascertain what linear errors had accumulated, and whether a whole remeasurement was advisable. This partial remeasurement was carried out in the years 1909-12, and included the measurement of a new base at Lossiemouth on the Moray Firth, and a small network of triangulation to connect this base to three of the original stations of the Principal Triangulation.

The result of this operation shows an error in the published values of the lengths of the sides of about one inch in one mile (1/60,000) in Morayshire.

We have now, therefore, four tests on the linear accuracy of the Principal Triangulation.

1. The three independently measured base lines at Lough Foyle, Salisbury Plain, and Lossiemouth.

2. The side Cassel-Les Harlettes of the French Meridional Arc, connected to the Principal Triangulation of the United Kingdom in 1861-62, and depending on the Paris Base (remeasured 1890).

The following table shows the comparison between the measured lengths of these bases and the same lengths as calculated through the Principal Triangulation from any other of the bases :—

TABLE 1.

The accordance of the bases as shown through the triangulation. (A + sign indicates that the calculated lengths of the bases in column 1 are greater than the measured.) Resulting differences are shown for each case both in units of the seventh place of logarithms and as a fraction.

Bases	Salisbury Plain		Lough Foyle		Lossiemouth		Paris	
	Log. Diff.	Corresponding Fraction	Log. Diff.	Corresponding Fraction	Log. Diff	Corresponding Fraction	Log. Diff	Corresponding Fraction
Salisbury Plain	...	...	−46·5	$\frac{1}{93000}$	− 95·8	$\frac{1}{45000}$	+ 8·7	$\frac{1}{505000}$
Lough Foyle .	+ 46·5	$\frac{1}{93000}$	...	...	− 49·3	$\frac{1}{88000}$	+ 55·2	$\frac{1}{79000}$
Lossiemouth .	+ 95·8	$\frac{1}{45000}$	+49·3	$\frac{1}{88000}$	...	...	+104·5	$\frac{1}{42000}$
Paris . .	− 8·7	$\frac{1}{505000}$	−55·2	$\frac{1}{79000}$	− 104·5	$\frac{1}{42000}$	...	...

If bases are regarded as errorless relatively to triangulation connecting them, the discrepancies between the measured lengths of bases and those same lengths calculated from adjacent bases will afford a method of comparing the relative precision of different systems.

Throughout a system homogeneous in size and shape of figure, and in precision of angular measurement, the linear errors generated would vary as the square root of the distance from the base. If, therefore, we refer to lists of the discrepancies between the measured and calculated lengths of bases in other National Triangulations and multiply each discrepancy by the factor $\sqrt{\frac{100}{d}}$ (where d is the distance in miles between the bases), we get a table which will serve to give a rough idea of the relative precisions of the various systems, and of what errors we should expect to find generated in them at a distance of 100 miles from the original base.

TABLE 2.[1]

Table showing the discrepancy between bases, assuming that this discrepancy varies as the square root of the distance, and reducing the length of 100 miles in each case.

National Surveys of	No. of Comparisons	Discrepancy in the 7th Place of Logarithms	Reference
Europe . .	36	52 $\left[\frac{1}{83000}\right]$	Report of the International Geodetic Association, 1893, p. 540 *et seq.*, omitting 5 bad connections in Russia (since remeasured)
India . . .	8	22 $\left[\frac{1}{197000}\right]$	Account of the Operations of the Great Trigl. Survey of India, Vols. 2, 6 and 12
South Africa .	13	47 $\left[\frac{1}{92000}\right]$	Reports of the Geodetic Survey of South Africa, Vols. 4 and 5, including two cases of a junction from a base to a side of previously adjusted Triangulation
United States of America .	20	36 $\left[\frac{1}{121000}\right]$	Report of the United States Coast and Geodetic Survey for 1900 and 1904. Professional papers of the Corps of Engineers, U.S. Army, No. 24
Total . .	77	Mean 44	Corresponding to $\frac{1}{99000}$.
United Kingdom	6	28·5	Corresponding to $\frac{1}{152000}$

The very close agreement between the Salisbury Plain and Paris bases is responsible for the high place taken in this table by the Principal Triangulation. If we neglect this connection the remaining five give the figure $\frac{1}{131000}$.

This table shows that the linear errors of the Principal Triangulation of the United Kingdom are in the same terms as those to be expected in Modern Triangulation carried out in chains over similar distances, and that, if the 700 miles of meridional arc between the Straits of Dover and Saxavord in the Shetland Islands were remeasured, it is not likely that the new measurement would differ from the old by more than 25 yards.

(ii) *The Precise Definition of Terms used in Higher Surveying.* *By* Captain H. G. LYONS, *F.R.S.*

(iii) *Longitude Work in Egypt.* *By* E. B. H. WADE.

In the last two years several longitudes have been measured in Egypt by exchange of telegraphic signals with Helwan Observatory. Mr. Knox Shaw determined local time at Helwan, using the Brunner transit instrument, and Mr. Wade employed the method of equal altitudes in the field. All star observations and telegraphic signals were chronographically registered, and

[1] Table 2 makes no claim to be exhaustive.

personal equation was measured at the end of each expedition. Each station was occupied on at least two nights. The stations referred to in the paper were el Daba'a, Mersa Matruh, Baqbaq, Siwa Oasis, and Khartum. The probable error arrived at for an adopted longitude (two nights) was discussed and found to be $\pm 0^s \cdot 05$. Values of personal equation and of adopted longitudes were given in the paper. Stress was laid on the utility of the method of equal altitudes in field work.

Local attraction in the prime vertical has been observed by Mr. Wade at the two ends of an east and west line from Helwan to Daqshur, 15 kilometres distant. Local attraction was first detected by mutual azimuth observations. The value found was confirmed by longitude determinations carried out just in the way described in the previous paragraph, except that an acetylene signalling lamp with occulting shutter communicating with a chronograph replaced the electric telegraph. To obtain further confirmation Messrs. Curry and Wade established a chain of seven stations along the line (produced somewhat each way) and determined intervals of longitude by a method of differential observation, for details of which reference must be made to the full paper. The easterly local attraction at Daqshur (relative to Helwan) was found to be:

By first method $-8'' \cdot 8$.
By second method $-6'' \cdot 9$.
By third method $-7'' \cdot 7$.

Intermediate stations gave for the most part intermediate values.

Messrs. Wade and Curry made a similar set further south at Biba. As a result of increased experience the accuracy attained was considerable. On several occasions the probable error of a longitude interval (one night) was as low as $\pm 0^s \cdot 02$. The local attraction on the Biba line was extremely small—a result which is in accordance with azimuth observations.

The differential method used should prove valuable in the detailed study of local attraction.

(iv) *The Precision of Field Observations for Latitude.* *By* B. F. E. KEELING, *M.A.*

This paper gave the results of observations made with the purpose of evaluating the real precision of the field latitudes of the Geodetic Survey of Egypt. The field programme consists of four pairs of stars, observed on at least three nights, the instrument used being a 10-inch Repsold theodolite.

At an early stage in the survey it was found that the probable error on a single night was in an average case about one-tenth of a second, but that unfortunately the agreement between the nightly means was not so close as was to be expected from such probable errors. Further investigation was thus evidently necessary, and accordingly the latitude of the survey point in the grounds of the Helwan Observatory was observed at approximately monthly intervals for the space of a year, using a procedure identical with that followed in the field. In all eleven series of observations were made.

The results showed very strikingly that the mean monthly latitudes were much less concordant than we have a right to expect from the individual probable errors. The monthly residuals ranged from minus nine-tenths to plus nine-tenths of a second, and five out of eleven were greater than four-tenths of a second. The probable error of a single month's observations, as computed from the eleven series, was five-tenths of a second, and this appears to be about the proper probable error to assign to the field latitudes of the Egyptian Geodetic Survey.

Attention was called to an analogous case at Kimberley in the South African Survey, where two series of latitudes, determined at an interval of six weeks, differed by nearly eight-tenths of a second.

In the concluding part of the paper the question was discussed whether the above results should be followed by a change of procedure in the Egyptian Survey.

The following Recommendation was passed :—

'That the terms First Order, Second Order, Third Order, and Fourth Order of Triangulation, as connoting definite degrees of precision, be used to describe triangulation, even though the terms now in use (*e.g.* Major, Minor, &c.), which have only a local significance, are also employed.'

The following Paper was then read :—

New Rainfall Maps of China. By W. G. Kendrew.

Discussion on Natural Regions of the World.

Opened by Professor A. J. Herbertson.

The idea of Natural Regions is not a new one. It has been used, consciously or unconsciously, by every traveller and geographical student with insight. What we are attempting now, is (i.) to divide the World into its Natural Regions, taking into account all the elements composing them, (ii.) to recognise and group Natural Regions into different classes and orders, and (iii.) to trace the consequences of the recognition of Natural Regions as entities.

(i) *The Natural Region.*

It is unnecessary to review the attempts to divide the Earth's surface into zones or regions each possessing some special property—land, water, igneous rocks, little or no rainfall, forests, a round-headed population, &c., &c. In this raw material the geographer finds certain relations between different elements, certain laws of combination. The elements and the combinations are far more complex than those of organic chemistry, but this complexity is no reason for not applying scientific methods to their investigation, nor for doubting that substantial results can be gained by their use. It is a reason for not consigning the study of Geography to the least experienced, but for giving it to the man who knows most. The only apology the geographer has to make is not for his subject, but for his ignorances.

The Natural Region is a vital unit as well as a physical one, a symbiosis on a vast scale. It is more than an association of plants, or of animals, or of men. It is a symbiotic association of all these, indissolubly bound up with certain structures and forms of the land, possessing a definite water circulation, and subjected to a seasonal climatic rhythm. As each element in a region has its own history, and as each varies in its rate of change, so the evolution of the region is highly complex.

(ii) *Types and Orders of Natural Regions.*

The advantage of classifying Natural Regions into types is obvious. Some of the larger ones with common morphological or climatic characters have long been recognised, *e.g.* Mountainous Lands, Plains, Monsoon Lands, Deserts, the Mediterranean Type of Region, &c. The systematic analysis and classification of all types are more recent efforts of geographers, who encounter two difficulties at the outset. One of these is to fix the limit of a natural region: Where does the Sahara begin and the Sudan end? The other is to distinguish properly between different orders or classes of natural regions: Are there to be two, or three, or four, or more? For instance, is it sufficient to divide the Monsoon Lands of Asia into great river basins, and each of them again into their minor basins, and these again into valleys and plains? Are the classes the same in rainy and rainless lands, in mountains and plains? Can we arrive at any grouping of order of natural regions as little objectionable as the biologist's organism, organ, tissue, cell?

Let us consider some of the simpler natural regions. In the Upper Thames Plain there are belts of (*a*) flowing water bordered by (*b*) meadow flood plains, (*c*) land rising above the flood level. Such belts are also found in the valleys

of the adjacent Cotswolds; but here all three are more complex—(*a*) the flowing water is not confined to the surface but permeates (*c*), which rises in steep banks above the irregular (*b*) flood-plains and forms a gently undulating and sloping surface very different from that of (*c*) in the Plain. Further, while the varieties of (*c*) in the Plain are mainly *i.* clay and *ii.* gravel-capped clay, the varieties of (*c*) in the Cotswolds are (*a*) the relatively flat land, *i.* very fertile cornbrash, *ii.* less fertile belts of Oolitic limestone, *iii.* cappings of gravel, *iv.* cappings of clay and (β) the steep slopes *i.* of the valleys, and *ii.* of the escarpment. There are also considerable differences in climate differentiating the Plain from the Scarped Ridges, and the climatic conditions within the natural region itself vary much more in the hilly region than they do in the plain. The Upper Thames Vale is, then, clearly a different natural region from the Cotswold Scarped Ridge. There are, however, vales and vales, scarped ridges and scarped ridges. The Upper Thames Vale is a much simpler variety of the same species of natural region than the Vale of Aylesbury, and the chalk-scarped ridges are a variety of the species differing from the oolitic limestone variety.

This grouping according to orographical conditions has its advantages, but others suggest themselves—more particularly the division into regions with a common drainage, *e.g.* the basins of Cherwell, Evenlode, Windrush, &c. Probably it is best to combine the two and see in the Cotswolds each incised river-valley as a sub-division of the natural region and the relatively flat land between as another sub-division. In plains the land between the rivers becomes by far the largest and most important sub-division.

We might look on the geological structure as the tissue of a region; but this geological structure does not suffice for a complete natural region. The water circulation must also be taken into account and the surface forms it has carved. In a mountainous area the valleys seem the natural units, divided by crests; in the plains the land between the rivers is the dominant element, and the rivers divide the natural regions. There are many intermediate forms between these extremes of mountain and plain, of which the Cotswolds are a good example.

Individual valleys, plateaus, and plains form simple geographical units.[1] Groups of different varieties of one or more of these constitute a new and more complex geographical order. These in their turn may be combined to form something more complex, such as the English Scarplands, the Welsh Highlands, &c. Yet more complex are associations of different natural regions such as form the British Isles or Iberia or Scandinavia.

There are therefore various orders of natural region, which we may roughly compare with the species, genera, orders, &c., of the biologist. For these we may have no definite names. Tentatively we may speak of species, genera, orders, classes of natural regions, even though this suggests biological analogies which may mislead the beginner. From this point of view valley, plain, and plateau are chorographical species each with many varieties. These themselves may be grouped into different genera of mountainous-, plateau-, and plain-lands, and these again into different orders of country, compounded of different combinations of these, which finally grouped together compose the continents.

This morphological or topographical classification is not enough. Climate must be taken into account in the larger divisions. The need for this is most easily recognised in the vast plains, where vegetation affords an index of climatic and edaphic influence. The botanist's classification into plant societies, associations and formations suggests new groupings, which have to be considered in making natural regions.

Beginning with the continents we might recognise major natural regions, each with its own climatic rhythm, and this acting on different genera of land forms. These topographical genera enable us to determine the geographical genera, which may themselves be sub-divided into different geographical species, each of which may have a number of varieties.

I venture to suggest as a convenient nomenclature for the geographical

[1] One other class—the cone, usually volcanic—may be mentioned. Only rainy regions are considered for the moment.

natural regions that we should consider each continent as composed of countries containing different regions divisible into districts each with its various localities or neighbourhoods. This would not interfere with such political terms as empire, state, province, county and parish.

Some of the attempts to divide the world into natural regions will be reviewed, if time permits.

Hitherto nothing has been said about Man. The different natural regions exist whether he is part of them or not. Even in the most complex class, the continent, he may not live at all, *e.g.* in Antarctica. In some natural regions he counts for no more than other animals. In others he has so profoundly altered the surface that it is necessary to consider him and his works in any classification. This is not merely the case in such districts as the Fens or the Lancashire coalfield, but even in such complex countries as China or those which border the Norland Seas of Europe, where much of the original forest has been converted into cultivated land. The concentration of man in cities obviously alters a locality.

We must also differentiate between two natural regions originally of the same type, in one of which man has settled in farms, villages, and towns and added a new characteristic to it; and we must also distinguish between a natural region in its present condition from the same region in an earlier state, when man did not play the part in it that he does at present, *e.g.* Egypt or Mesopotamia, for we have also to consider reversion.

Men in the natural region may be compared with nerve-cells in an animal. Some have a highly developed, others a very simple undifferentiated nervous (social) system.

(iii) *The Significance of Natural Regions.*

There are many important consequences which cannot be examined in detail now. It is, however, desirable to point out that while it is possible to study men in families, races, &c., without taking into account that they form but a part of a more comprehensive entity, to do so is to deal with less than the whole problem. It does not suffice to give once and for all a brief description of the physical conditions of a country as a prelude to the account of the history of its inhabitants. The history is incomplete which does not consider both together at all stages. Neither is passive, neither remains unchanged when man becomes important enough to have a recorded history. The changes are not usually sharp and dramatic as in the American Prairies or in South Wales, but slow and subtle as in most countries of Europe. We are accustomed to think of the changes in the men; we rarely consider the changes in the region, which are also of vital significance.

The entity higher than the individual is not the family, nor the race, nor any association of men alone, but the more complex association of the Natural Region. This has always been so, and until we recognise the fact neither the history of man, nor his relation to the universe, nor even his very pressing present problems, economic or political, can be properly understood. This is much too vast a subject to examine in detail on the present occasion; but I should like to add a note of warning to those who imagine that any such conclusions do more than show that the problems of the universe are somewhat more complex than is commonly supposed. It is not meant that the geographer can solve them; only that they cannot be solved without taking these geographical considerations into account.

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

PRESIDENT OF THE SECTION.—REV. PHILIP H. WICKSTEED, M.A.

THURSDAY, SEPTEMBER 11.

The President delivered the following Address:—

The Scope and Method of Political Economy in the Light of the 'Marginal' Theory of Distribution.[1]

THE subject on which I desire to address you this morning is the bearing of what is known as the 'marginal theory of distribution' upon the scope and method of economic study.

I address myself primarily to those who already accept this theory, inviting their attention to the modifications it is already introducing into current conceptions of Political Economy and its relation to other studies, and urging the necessity of accepting the change more frankly and pressing it further.

But at the same time I think we shall find that the best approach to our proper subject is through a summary exposition, if not a defence, of the theory itself.

To begin with, then, the marginal theory of distribution rests upon a theory of exchange value. This latter theory is very easily stated in mathematical language; for it simply regards value in exchange as the first derived or 'differential' function of value in use; which is only as much as to say, in ordinary language, that what a man will give for anything sooner than go without it is determined by a comparison of the *difference* which he conceives its possession will make to him, compared with the difference that anything he gives for it or could have had instead of it will or would make; and, further, that we are generally considering in our private budgets, and almost always in our general speculations, not the significance of a total supply of any commodity—coals, bread, or clothes, for instance—but the significance of the difference between, say, a good and a bad wheat harvest to the public, or the difference between ten and eleven loaves of bread per week to our own family, or perhaps between ten days and a fortnight spent at the seaside. In short, when we are considering whether we will contract or enlarge our expenditure upon this or that object, we are normally engaged in considering the difference to our satisfaction which differences in our several supplies will make. We are normally engaged, then, not in the consideration of totals, either of supplies or of satisfactions, but of differences of satisfaction dependent upon differences of supplies.

According to this theory, then, what I am *willing* to give for an increase in my supply of anything is determined by the difference it will make to my satisfaction, but what I shall *have to* give for it is determined by the difference it would make to the satisfaction of certain other people, for if there is anyone to whom it will make more difference than it will to me, he will be ready

[1] This Address in a revised form, and with diagrams illustrative of the theory of the market, will appear in the *Economic Journal* for March 1914.

to give more for it, and he will get it, while I go without. But again, since the more he has the less difference will a still further increase make to him, and the less I have the more difference will a still further decrease make to me, we shall ultimately arrive at an equilibrium; what I am willing to give and what I am compelled to give will coincide, and the difference that a little more or a little less of any commodity which I habitually consume makes to my estimated satisfaction will be identical with the similar estimated difference to any other habitual consumer.

Now it is obvious (though it is by no means always observed) that this identical or equilibrated 'difference of estimated satisfaction' must be understood and measured objectively, not subjectively. If two men estimate the difference that a given addition or subtraction of supply would make to them at the same money value, it shows that this increment or decrement occupies the same place on their respective scales of preference relatively to all other things or services that could be obtained for the money. This much it tells, but no more. The actual experiences of the two men cannot indeed be compared, but an increment of supply that stands on a poor man's relative scale of preferences exactly where it does on a rich man's, may, and 'in our circumstance and course of thought' often must, depart indefinitely from it in its vital significance.

Such, then, is the theory of exchange, which I should like to call the 'differential theory,' that underlies the theory of distribution we are presently to examine. It has been objected to it that since it only asserts that a man will never give more for a thing than he thinks it is worth, and can never get it for less than the man who has it believes he could get from someone else or thinks it worth to himself, it comes down to the simple assertion that value in exchange—is value in exchange. I am quite willing to accept this reproach, only I must be allowed to add something to it and to say, 'The differential theory of value in exchange asserts that value in exchange is value in exchange. All other theories assert that it is not.'

Chief amongst these other theories in historical and polemical dignity, and in tenacity of life, is the 'cost of production' theory; which, in its crudest form, asserts that the true measure of exchange value is to be found not in the estimated worth of a thing, but in the amount of labour that has gone to its production. This theory, I think it is safe to say, is now discredited and hardly dares to announce itself openly. The actual nature of the connection between 'cost of production' and market price, or exchange value, and the true analysis of the tendency to coincidence between them are now clearly understood. When the production of two different commodities involves the same cost, and one of them has a higher market price, because it has a higher differential significance to the purchasers, then enterprise will naturally be directed to the production of the one rather than of the other; and as this goes on, and the supply increases, the differential significance, and so the exchange value, of the favoured product will decline, until equilibrium is reached. Thus the idea that cost of production already incurred determines exchange value turns out to be a reversal of the true relation. It is the anticipated value in exchange that determines what cost of production the producer will be willing to encounter, and if a relatively low cost of production ultimately brings down prices it is only because it determines an increased supply.

All this is well understood; but nevertheless the cost-of-production fallacy assumes subtle disguises; and theories of distribution based upon it, or at least tainted by it, are perpetually reappearing. I shall not stay to examine it further; but one of the chief reasons for reconsidering the current methods of economic exposition is, to my mind, the need of a more complete and drastic cleansing of economic doctrine from the baneful sequelæ of this disease of its youth.

The ground is now clear for a step forward along the main line of our advance. The differential theory of exchange values carries with it a corresponding theory of distribution, whether we use this term in its technical sense of the division of a product amongst the factors that combine for its production, or whether we employ it as equivalent to 'administration,' and are thinking of the administration of our personal resources; that is to say, their distribution amongst the various objects that appeal to us; or again, the distribution, under

economic pressures, of the sum of the industrial resources of a society amongst the objects that appeal to its members.

A brief exposition will suffice. We have pointed out that to any individual the differential significance of a unit of supply of any commodity or service declines as the supply increases. In our own expenditure we find that current prices (our individual reaction on the market being insensible) fix the terms on which the various alternatives offered by the whole range of commodities and services in the circle of exchange are open to us. Obviously, if the differential satisfaction anticipated from one purchase exceeds that which the same money would procure from another, we shall take the preferable alternative, and shall so regulate our expanding or contracting supplies that the differential satisfactions gained or lost from a given small increase or decrease of expenditure upon any one of our different objects of interest will be identical. Into the practical difficulties that prevent our ever actually reaching this ideal equilibrium of expenditure I will not here enter; but I must call attention to the identity in principle of this analysis of the internal economy of our own choice between alternatives, tending to a subjective equilibrium between the differential significances of different supplies to the same person, and the corresponding analysis, given on a previous page, of the process by which an objective equilibrium is approached between the differential significances of the same supply to different persons.

And this observation introduces another of extreme importance. In our private administration of resources we are concerned both with things that are and with things that are not in the circle of exchange, and the principle of distribution of resources is identical in both cases. The independent student who is apportioning his time and energy between pursuing his own line of research and keeping abreast of the literature of his subject is forming estimates of differential significances and is equating them to each other just as directly as the housewife who is hesitating between two stalls in the market; and, more generally, the inner core of our life problems and the gratification of all our ultimate desires (which are indeed inextricably interlaced with our command of exchangeable things, but are the ends to which the others are but means) obey the same all-permeating law. Virtue, wisdom, sagacity, prudence, success, imply different schemes of values, but they all submit to the law formulated by Aristotle with reference to virtue, and analysed by modern writers with reference to business, for they all consist in combining factors *κατ' ὀρθὸν λόγον*, *in the right proportion*, as fixed by that distribution of resources which establishes the equilibrium of their differential significances in securing the object contemplated, whether that object be tranquillity of mind, the indulgence of an overmastering passion or affection, the command of things and services in the circle of exchange, or a combination of all these, or of any other conceivable factors of life.

Now this dominating and universal principle of the distribution of resources, as we have seen, tends, by the instrumentality of the market, to secure an identity in the relative positions of increments of all exchangeable things upon the scales of all the members of the community amongst whom they are distributed. For if, amongst the things he possesses, A. finds one a given decrement in which would make less difference to him, as measured in increments of other exchangeable things, than the corresponding increment would make to B. (who is assumed to have a certain command of exchangeable things in general), obviously there is a natural gain in B. giving for the increment in question what is less than worth it to him but more than worth it to A. There is equilibrium therefore only when a decrement in any man's stock of any exchangeable thing would make more difference to him, as measured in other exchangeable things, than the corresponding increment (measured in the same terms) would make to anyone else. Hence all those who possess anything must, in equilibrium, value it more, differentially or incrementally, than anyone who does not possess it, provided that this latter does possess something, and provided that 'value' is measured in exchangeable things.

But this last qualification is all-important. The market tends to establish an identity of the place of the differential value of any commodity amongst all exchangeable things on everybody's scale of preferences, and further to secure that it is higher on the scale of everyone that has it than on the scale of anyone

who has it not; so that to that extent it must always tend to go and to stay where it is most significant. But then exchangeable things are never really the ultimately significant things at all. They are means. The ends, which are always subjective experiences of some kind, whether of the senses or the will or the emotions, are not in any direct way exchangeable; and there is no machinery to secure that increments and decrements of exchangeable things shall in industrial equilibrium take the same place and have the same differential significance on the scales of any two men when measured not in terms of other means, but in terms of ends. If two men habitually spend a portion of their resources on food and on books, there is a presumption that to both of them the differential significance of a shilling's-worth of food and of a volume of Everyman's or the Home University Library is equivalent. But there is no presumption whatever that the vital significance of either one or the other is identical to the two men as measured, not each in terms of the other, but each in the degree to which it ministers to the ultimate purposes of its possessor or consumer; in the pain that its absence or the pleasure that its presence would give him; or in its ultimate significance upon his life. Granted that x makes just as much difference, both to you and to me, as y does, it does not follow that either x or y makes the same difference to you that it does to me.

Our next step will reveal some of the bearings of this distinction; for we are now to consider 'distribution' in its technical sense of the principle of sharing of a commercial product amongst the factors of production. Now a commercial product is something exchangeable, and what is actually shared amongst the factors is not the product itself, but the command of exchangeable things in general that it secures in the market. We are therefore now engaged upon a strictly economic problem, whereas we have hitherto been dealing with the wider problem of distribution of resources in general, whether material or immaterial, economic or non-economic; and it is instructive to note that we shall not have to introduce any new principle or formulate any new law whatever when we pass on to the specifically economic problem. For economics have no laws of their own, though they furnish a vaguely defined but clearly characterised field for the application of certain general laws.

Before illustrating this truth by applying the general law of distribution to the special problem of economic or industrial distribution, let us attempt to determine more closely the characteristic of the economic field of investigation itself. Naturally there is no sharp line that marks off the economic life, and we must not expect to find a rigid definition of it; but I take it that if I am doing a thing because I want it done for its own sake (not necessarily *my* own sake, in any restricted sense, for it may primarily concern someone else in whom I am interested out of pure good will) or am making a thing that I require for the supply of my own desires or the accomplishment of my own purposes; if, in fact, I am engaged in the direct pursuit of my own purposes, or expression of my own impulses, my action is not economic. But if I am making or doing anything not because I have any direct interest in it, but because someone else wants it, and that other person will either do what I want done or put me in command of it, then I am furthering his purposes as a means of furthering my own. I am indirectly forwarding my purposes by directly forwarding his. This is the nature of the economic relation, and the mechanism or articulation of the whole complex of such economic relations is the proper subject of economic investigation. Thus, if a peasant adorns his ox-yoke with carving because he likes doing it and likes it when done, or if he carves a stool for his friend because he loves him and likes doing it for him and believes he will like it when done, the action is not economic; but if he gets a reputation for carving and other peasants want his work, he may become a professional carver and may carve a yoke or a stool because other people want them and he finds that supplying their wants is the easiest way for him to get food and clothes and leisure for his own art, and all things else that he desires. His artistic work now puts him into an economic relation with his fellows; but this example serves to remind us that there may be an indefinite area of coincidence between the economic and non-economic aspects of a man's occupations and relations. That man is happy indeed who finds that in expressing some part of his nature he is providing for all his nature's wants, or that in rendering services to friends in which he delights he is putting himself in command of all the services he him-

self needs for the accomplishment of his own purposes. A perfect coincidence of this nature is the dream of modern Utopias; but my present subject is only the economic side of the shield.

The economic organism, then, of an industrial society represents the instrumentality by which every man by doing what he can for some of his fellows gets what he wants from others. It is true, of course, that those for whom he makes or does something *may* be the same as those from whom he gets the particular things he wants. But this is not usual. In such a society as ours the persons whom a man serves are usually incapable of serving him in the way he desires, but they can put him in command of the services he requires, though they cannot render them. This is accomplished by the instrumentality of money, which is a generalised command of the services and commodities in the circle of exchange; 'money' being at once a standard in which all market prices (or objective places of differential significances amongst themselves) are expressed, and a universal commodity which everyone who wishes to exchange what he has for what he wants will accept as a medium, or middle term, by which to effect the transformation. Thus in most commercial transactions one party furthers a specific purpose of the other, and receives in exchange a command, defined in amount but not in kind, of services and commodities in general; the scale of equivalence being a publicly recognised thing announced in current market prices. Every member of the community who stands in economic relations with others alternately generalises his special resources and then specialises his general resources, first directly furthering someone else's purposes and then picking out the persons who can directly further his. Thus each of us puts in what he has at one point of the circle of exchange and takes out what he wants at another. Being out of work is being unable to find anyone who values our special service enough to relinquish in our favour a command of services in general which we will consent to accept in return. It is the failure to find anyone who will specialise his general command, into our particular service, on terms that suit us.

We return now to the problem of economic distribution. Land, manifold apparatus, various specialised faculties of hand, eye, and brain, are essential, let us say, to the production of some commodity valued by someone, it does not matter who, for some purpose, it does not matter what. None of these heterogeneous factors can be dispensed with, and therefore the product in its totality is dependent upon the co-operation of each one severally. But there is room for wide variety in the proportions in which they are combined, and whatever the existing proportion may be each factor has a differential significance, and all these differential significances can be expressed in a common unit; that is to say, all can be expressed in terms of each other, by noting the increment or decrement of any one that would be the equivalent of a given decrement or increment of any other: equivalence being measured by the neutralising of the effect upon the product, or rather, not upon the material product itself, but the command of generalised resources in the circle of exchange for the sake of which it is produced. The manager of a business is constantly engaged in considering, for instance, how much labour such-and-such a machine would save; how much raw material a man of such-and-such character would save; what equivalent an expansion of his premises would yield in ease and smoothness in the conduct of business; how much economy in the shop would be effected by a given addition to the staff in the office, and so on. This is considering differential significances and their equivalences as they affect his business. And all the time he is also considering the prices at which he can obtain these several factors, dependent upon their differential significances to other people in other businesses. His skill consists, like that of the housewife in the market, in expanding and contracting his expenditure on the several factors of production so as to bring their differential significances to himself into coincidence with their market prices. And note that the same principle can be applied without any difficulty to such immaterial factors of efficiency as 'good will,' or notoriety; but it would delay us too long to work this out or to anticipate possible objections. A hint must suffice.

Here, then, we have a firm theoretical basis for the study of distribution, independent of the particular form of organisation of a business. Whether those in command of the several factors of production meet and discuss the

principles upon which the actual proceeds of the business shall be divided, when they are realised; or whether some one person takes, on his own behalf or on behalf of a group of others, the risks, and discounts the estimated significance of the several factors, buying up their several interests in the product, in the form of wages and salaries, interest, rent, payment for machinery and raw material, and so forth; or whatever other mechanism may be adopted, the underlying principle is the same. The differential equivalence of the factors of production reduces them to a common measure, and when they are all expressed in the same unit the problem of the division of the product amongst them is solved in principle.

The exposition I have now given of the underlying principle of what are usually called 'marginal,' but what I should prefer to call 'differential' economics, has been planned not with a view to meeting objections (except incidentally), but with a view to leading up to the changes it involves in our conception of the scope and the method of economic study. And, as almost all that I want to say is already implied or held in solution in this exposition, I hope that you will not grudge the time spent upon it.

In a word, then, the differential method in economics must, I conceive, tend to enlarge and to harmonise our conception of the scope of the study, and to keep it in constant touch with the wider ethical, social, and sociological problems and aspirations from which it must always draw its inspiration and derive its interest. And at the same time it must indefinitely simplify its narrower and more technical branches, and must purge them of all kinds of distinctions and discussions which, whatever practical or technological value some of them may have, can only confuse a theoretical economic inquiry.

I will begin by considering the expansion of scope and the knitting up of economics with all the vital sciences. If we really understand and accept the principle of differential significances we shall realise, as already pointed out, that Aristotle's system of ethics and our reconstructed system of economics are twin applications of one identical principle or law, and that our conduct in business is but a phase or part of our conduct in life, both being determined by our sense, such as it is, of differential significances and their changing weights as the integrals of which they are the differences expand or contract. Cæsar, 'that day he overcame the Nervii,' being surprised by the enemy, contracted his exhortation to the troops, but did not omit it. In his distribution of the time at his disposal the differential significance of prompt movement was higher than usual in relation to the differential significance of stirring words from their beloved and trusted commander addressed to the soldiers as they entered upon action. An ardent lover may decline a business interview in order to keep an appointment with his lady-love, but there will be a point at which its estimated bearing upon his prospects of an early settlement will make him break his appointment with the lady in favour of the business interview. A man of leisure with a taste for literature and a taste for gardening will have to apportion time, money, and attention between them, and consciously or unconsciously will balance the differential significances involved against each other. All these, therefore, are making selections and choosing between alternatives on precisely the same principle and under precisely the same law as those which dominate the transactions of the housewife in the market, or the management of a great factory or ironworks, or the business of a bill-broker.

A full realisation of this will produce two effects. In the first place it will put an end to all attempts to find 'laws' proper to our conduct in economic relations. There are none. Hitherto economists for the most part have been vaguely conscious that the ultimate laws of economic conduct must be psychological, and, feeling the necessity of determining some defining boundaries of their study, have sought to make a selection of the motives and aims that are to be recognised by it. Hence the simplified psychology of the 'economic man' now generally abandoned—but abandoned grudgingly, by piecemeal, under pressure, and with constant attempts to patch up what ought to be cast away. There is no occasion to define the economic motive, or the psychology of the economic man, for economics study a type of relation, not a type of motive, and the psychological law that dominates economics dominates life. We may either ignore all motives or admit all to our consideration, as occasion demands, but there is no rhyme or reason in selecting certain motives that shall and certain others that shall not be recognised by the economist.

In the second place, when taken off the wrong track we shall be able to find the right one, and shall understand that the proper field of economic study is, in the first instance, the type of relationship into which men spontaneously enter, when they find that they can best further their own purposes by approaching them indirectly. There is seldom a direct line by which a man can make his faculties and his specialised possessions minister continuously to all his purposes, or even to the greater part or the most importunate part of them. He must find someone else to whose purposes he can directly devote his powers or lend his resources in order that he may generalise his specific capacity or possession, and then again specialise this generalised command in the direction his tastes or needs dictate. The industrial world is a spontaneous organisation for transmuting what every man has into what he desires, wholly irrespective of what his desires may be.

And, in the third place, this truer conception of the economic field of investigation, coupled with the sense of the unity of fundamental law and fundamental motive that sway our economic and our non-economic action, will throw a constantly increasing emphasis upon the fact that our economic life is not and cannot be isolated, but is at every point combined with the direct expression of character and indulgence of taste, while the human relations into which it brings us are constantly waking in us a direct interest (whether of attraction or repulsion) in those purposes of others which we are directly furthering as an indirect means of furthering our own, purposes which we have indeed adopted, but beyond which we look whenever we reflect. There is no reason why means should not, to an undefined extent, be from the beginning, or become in course of time, ends in themselves, while still continuing to be means; nor, alas! is there any guarantee that they will not be, or will not become, negative and repellent as ends, either through physical weariness or moral repulsion. Perhaps most men's 'occupations' combine both characteristics.

Again, the realisation of the exact nature of the economic organisation as a machinery for combining in mutual helpfulness persons whose ends are diverse, will drive it home to our consciousness that one man's want is another man's opportunity, and that it may serve a man's turn to create a want or a passion in another in order that he may find his opportunity in it. All along the line, from a certain type of ingenious advertiser to the financier (if he really exists) who engineers a war in order that he may arrange a war loan, we may study the creation of wants and passions, destructive of general welfare, for the sake of securing wealth to individuals. And we may realise the deeply significant truth that to any individual the full discharge of his industrial function—that is to say, the complete satisfaction or disappearance, by whatever means, of the want which he is there to satisfy—must be, if he contemplates it, a nightmare; for it would mean that he would be 'out of work,' that because no one wants what he can give no one wants him, and neither will anyone give him what he wants.

Yet again, in our industrial relations the thing we are doing is indeed an end, but it is someone else's end, not ours; and, as far as the relation is really economic, the significance *to us* of what we are doing is measured not by its importance to the man for whom it is done, but by the degree to which it furthers our own ends. There can, therefore, be no presumption of any coincidence between the social significance of our work and the return we receive for it. We cannot say 'What men most care for they will pay most for, therefore what is most highly paid is most cared for,' for (sometimes to our positive knowledge, and generally 'for all we know') it is different men who express their eagerness for the different things we are comparing, by offering such-and-such prices, and those who offer little money for a thing may do so not because what they demand signifies so little, but because what they would have to give, or to forgo, for it signifies so much. They may offer little for a thing not because its possession matters so little, but because their possession of anything, including this particular thing, matters so much.

These and other such considerations will not directly affect our exposition of the mechanism of the market, the central phenomenon of the industrial world, but they will profoundly affect the spirit in which we approach, and in which we conduct, our investigation of it. For we shall not only know but shall always

feel that the economic machine is constructed and moved by individuals for individual ends, and that its social effect is incidental. It is a means, and its whole value consists in the nature of the ends it subserves and its efficacy in subserving them. The collective wealth of a community ceases to be a matter of much direct significance to us, for if one man has a million pounds, and a hundred others have ten pounds each, the collective wealth is the same as if the hundred and one men had a thousand each. What are we to expect from a survey made from a point of view from which these two things are indistinguishable? The market does not tell us in any fruitful sense what are the 'national,' 'social,' or 'collective' wants, or means of satisfaction, of a community, for it can only give us *sums*, and the significance of a sum varies indefinitely, according to its distribution.

If we reflect on these things—and the study of differential significances forces us to reflect upon them—we shall never for a moment, in our economic investigations, be able to escape from the pressure of the consciousness that they derive their whole significance from their social and vital bearings, and that the categories under which we usually discuss them conceal rather than reveal their meaning. We shall understand that this ultimate significance is determined by ethical considerations; that the sanity of men's desires matters more than the abundance of their means of accomplishing them; that the chief dangers of poverty and wealth alike are to be found in degeneracy of desire, and that the final goal of education and of legislation alike must be to thwart corrupt and degrading ends, to stimulate worthy desires, to infect the mind with a wholesome scheme of values, and to direct means into the channels where they are likeliest to conduce to worthy ends.

To sum up this branch of our examination, the differential theory of economics will never allow us to forget that organised 'production,' which is the proper economic field, is a means only, and derives its whole significance from its relation to 'consumption' or 'fruition,' which is the vital field, and covers all the ends to which production is a means; and, moreover, the economic laws must not be sought and cannot be found on the properly economic field. It is on the vital field, then, that the laws of economics must be discovered and studied, and the data of economics interpreted. To recognise this will be to humanise economics.

The merit of our present organisation of industry is to be found in the extent to which it is spontaneous, and lays every man, whatever his ends, under the necessity of seeking some other man whom he can serve in order to accomplish them. So far it is social, for it compels the individual to relate himself to others. But the more we analyse the life of society the less can we rest upon the 'economic harmonies'; and the better we understand the true function of the 'market,' in its widest sense, the more fully shall we realise that it never has been left to itself, and the more deeply shall we feel that it never must be. Economics must be the handmaid of sociology.

It is of good augury that so large a part of the economic work now being done is being done by sociologists and social and administrative reformers, in the full consciousness of this relationship. It is perhaps of still better augury that the last considerable work of a leading economist is devoted to a searching study of the relation of *Wealth* to *Welfare*.

I now turn to the other set of considerations suggested by the recognition of the differential theory of economics; and I would again remind you that I am addressing myself to those who accept this theory in its full scope and without reserve or qualification. I am not here to defend it, but, assuming its truth, to point out some of the main consequences of its acceptance.

At the root of all lies a profound modification of our conception of the nature and function of the 'market' itself. The differential theory when applied to exchangeable things tells us that there is equilibrium only when an exchangeable commodity is so distributed that everyone who possesses it assigns the same place to its differential value, amongst those of other commodities of which he has a supply; and that this place is a higher one than it occupies on the relative scale of anyone who does not possess it. What this place is—that is to say, the differential equivalence of the commodity in terms of other commodities, when equilibrium is established—is fixed absolutely by two determinants. These are;

(1) The tastes, desires, and resources of the individuals constituting the society. When objectively measured and expressed these individual desires for any one commodity can be represented by curves capable of being summed; and the resultant curve, objectively homogeneous but covering undefined differences of vital or subjective significance, is usually called, so far as it is understood and realised, the 'curve of demand.' This is one of the determinants we are examining, and it represents a series of hypothetically co-existing relations between given hypothetical supplies and corresponding differential significances. It is a functional curve. (2) The amount of the actual supply existing in the community. This is not a curve at all, but an actual quantity. It is not a series of co-existing relations, but one single fact, and it determines which of the series of hypothetical or potential relations represented by the curve shall be actually realised.

But what about the 'supply curve' that usually figures as a determinant of price co-ordinate with the demand curve? I say it boldly and baldly: There is no such thing. What usually figures as such is merely a disguised and therefore unrecognised portion of the 'demand curve'; for it is the register of a series of hypothetical relations between supply and differential significance, and therefore it is included in its entirety in our (1).

But neither our (1) nor our (2) is, generally speaking, accurately known by anyone when the market opens, and the 'higgling of the market,' though not theoretically a force that determines, is a machinery that discovers the character of the relevant portion of the curve and the exact point of it that the supply determines.

Diagrams of intersecting curves (and corresponding tables) of demand prices and supply prices are therefore profoundly misleading. They concentrate the attention of the student upon distinctions which have no theoretical relevancy; they co-ordinate as two determinants what are really only two arbitrarily and irrelevantly separated portions of one; and they conceal altogether the existence and functions of what really is the second determinant. For it will be found on a careful analysis that the construction of a diagram of intersecting demand and supply curves always involves, but never reveals, a definite assumption as to the amount of the total supply possessed by the supposed buyers and the supposed sellers taken together as a single homogeneous body, and that if this total is changed the emerging price changes too; whereas a change in its distribution (if the preferences of the parties concerned remain the same, so that the collective curve is unaffected, while the component or intersecting curves change) will affect the extent of the transfer consequent on the opening of the market, but not the market, or equilibrating price itself, which will come out exactly the same. Naturally, for neither the one curve nor the one quantity which determine the price has been changed.[1]

The curve of supply prices, then, is an impostor. It is a fraudulent *alias* of a portion of the demand curve. But so far we have only dealt with the market in the narrower sense. Our investigations throw sufficient light on the distribution of the hay harvest, for instance, or on the 'catch' of a fishing fleet. But where the production is continuous, as in mining and in ironworks, will the same theory still suffice to guide us? Here again we encounter the attempt to establish two co-ordinate principles, diagrammatically represented by two intersecting curves. Though the 'cost of production' theory of value is generally repudiated, we are still too often taught to look for the forces that determine the stream of supply along two lines, the value of the product, regulated by the law of the market, and the cost of production. But what is cost of production? In the market of commodities I am ready to give as much as the article is worth to me, and I cannot get it unless I give as much as it is worth to others. In the same way, if I employ land or labour or tools to produce something, I shall be ready to give as much as they are worth to me and I shall have to give as much as they are worth to others—always, of course, differentially. Their worth to me is determined by their differential effect upon *my* product, their worth to others by the like effect upon *their*

[1] See my 'Common Sense of Political Economy,' Book II., ch. iv., Macmillan. 1910.

products (or direct fruitions, if they do not apply them industrially). Again we have an *alias* merely. Cost of production is merely the form in which the desiredness a thing possesses for someone else presents itself to me. When we take the collective curve of demand for any factor of production we see again that it is entirely composed of demands, and my adjustment of my own demands to the conditions imposed by the demands of others is of exactly the same nature whether I am buying cabbages or factors for the production of steel plates. I have to adjust my desire for a thing to the desires of others for the same thing, not to find some principle other than that of desiredness, and co-ordinate with it as a second determinant of market price. The second determinant, here as everywhere, is the supply. It is not until we have perfectly grasped the truth that costs of production of one thing are nothing whatever but an *alias* of efficiencies in production of other things that we shall be finally emancipated from the ancient fallacy we have so often thrust out at the door, while always leaving the window open for its return.

I now turn to some of the most obvious consequences of the differential theory of distribution. They are all included in the one statement that when fully grasped this theory must destroy the very conception of separate laws of distribution, such as the law of rent, the law of interest, or the law of wages. It is by determining the differential equivalence of all the factors of production, however heterogeneous, that we reduce them to a common measure and establish the theory of distribution; just as it is by determining the differential equivalence of all our pursuits and possessions that we attempt to place a shilling or an hour or an effort of the mind where it will tell best, and so distribute our money or time or mental energy well. There can no more be a law of rent than there can be a law of the price of shoes distinct from the general law of the market. The way in which the several factors render this service to production differs, but the differential service they render is in every case identical, and it is on this identity or equivalence of service that the possibility of co-ordinated distribution rests. So the economist, though he may begin by giving precision to the student's idea of *how* 'waiting,' for example, or tools, or mere command of 'extension' in space, or manual skill, or experience, or honesty, may affect the value of the product, must end by showing him that their distributive share of the product depends not upon *the way in which* they affect the product (wherein they are all heterogeneous), but on the differential *amount* of their effect (wherein they are all alike). The law of distribution, then, is one, and is governed not by the differences of nature in the factors, but by the identity of their differential effect. With this searchlight we must scrutinise the body of current economic teaching, and must cast out the mischievous survivals that deform it.

I will conclude, then, with a few illustrations of the course which I conceive this process must follow. But first I must turn aside to utter a warning and emphasise a distinction.

I have throughout spoken of *differential*, rather than *marginal* significances; for there is a fatal ambiguity in the use of the word 'marginal.' And yet, after all, I have felt like the man who 'did flee from a lion and a bear met him; or went into the house and leaned his hand on the wall, and a serpent bit him,' for by a singular perversity of fate or fashion a closely similar ambiguity besets the word 'differential' itself, and yet another the equally appropriate term 'incremental.' All these words have been preoccupied; and curiously enough it is speculations on the nature of rent or projects concerning land that have done the mischief in every case. 'Increment,' instead of suggesting a small homogeneous addition to any magnitude whatever, at once suggests to the reader of economic literature the 'unearned increment of land,' so that the 'incremental value,' 'efficacy' or 'significance' of anything cannot conveniently carry its proper meaning of the value attached to a small increment or decrement of anything, varying with the expansion or contraction of the supply. This is the conception I have indicated by the term 'differential.' But here again we are forestalled. Differential payment, for instance, would generally be understood by readers of economic literature to mean payment made for some articles in excess of that made for others in consideration of their superiority. Thus, if I were to say that 'rent is a differential charge,'

I should be supposed to mean that what you pay for a certain piece of land as rent represents the superiority of that piece of land to another that you can get for nothing. In this use of the word everything depends upon the different *quality* of the things compared. But what I want is a word which shall always carry the underlying assumption that we are considering the expansion and contraction of a *homogeneous* supply, the 'differential' value of that supply being a function of its breadth or magnitude.

Again, the same theory of rent which regards it as a differential charge, in the sense of a charge due to an inherent difference of quality in the things charged for, assumes that there is some land which bears no rent at all. This is the land on the 'margin' of cultivation. Hence 'marginal' has come to be used in economic literature to signify the lowest grade or quality of any commodity, or service, or the least favourable set of conditions, that just hold their footing in any industry. Thus the marginal land would mean the worst land under cultivation, the marginal workman the least efficient man in actual employment, the marginal conditions of an industry the least advantageous conditions under which it is actually conducted, and, I suppose, the marginal grade of potatoes or wheat the worst quality actually in the market; or to the hungry individual the marginal mouthful of beef would be the one just not rejected and left on the plate because too largely composed of 'veins' to be eaten, even if no more of any kind were to be had.

Now attempts have been made to erect a theory of distribution upon the consideration of 'margins' in this sense. The 'marginal' man, working on the 'marginal' land, under the 'marginal' conditions, and with the 'marginal' appliances, is taken as the ultimate basis of the pile, and wages, rent and interest are explained as 'differential' in their nature; that is to say, as due to the superiority in quality, position, or point of application, of such-and-such work, land, or apparatus, over the 'marginal' specimens.

I do not stay to examine this theory on its merits; but it is necessary to insist on the almost incredible fact that there is constant confusion between it and what I have tried to expound as the 'differential' theory of distribution, simply because they can both be described as 'marginal,' and the term 'differential,' though in quite divergent senses, may be introduced in the exposition of either.

Once again, then, if I speak of the differential or marginal significance of my supply of bread and milk, and say that it depends, *ceteris paribus*, upon how many loaves of bread and how many pints of milk I take, I am supposing all the bread and milk to be of the same quality. And if I speak of the differential or marginal significance of labour in a particular industry, I am either speaking of a uniform grade of labour or of different grades reduced to some common measure and expressed in one and the same unit, and I mean the significance which such a unit has when it is one out of so many others like itself. Thus, in my use of the word, there is no earmarked marginal unit, which is such in virtue of its special quality. Any one of 100 units has exactly the same marginal value; but as soon as one unit is withdrawn, all the remaining 99 have a higher marginal value; and when one is added, all the 101 a lower.

The only word I can think of free from misleading associations would be 'quotal'; for *quotus* means (amongst other things) 'one out of how many,' and so *quotal* significance might mean the significance which a unit has when associated with such-and-such a number of others *homogeneous with itself*.

And now let us turn again to the further consideration of the changes of method and the purgings which seem inevitably to follow upon the full recognition of the differential principle in economics. Severe selection and limitation is, of course, necessary, and I think we cannot do better than take up a few of the current phrases or conceptions and diagrammatic illustrations connected with the phenomenon of rent. Antecedently we must expect that as there is no theoretical difference between the part played by land and that played by other factors of production (or more direct ministrants to enjoyment), so there can be no general assertion about rent and land which is at once true and distinctive; for if true it must be based on that aspect of land which expresses its function in a unit common, say, to capital, and which brings its

differential significance, upon which all depends, under the same law; and therefore it cannot be distinctive of land.

Let us test the truth of these anticipations. We will begin with Ricardo's celebrated law of rent. Granted that land of a certain quality can be had for nothing, and is worth cultivating, land of a better quality will bear a rent equivalent to its superior yield to the same labour and capital. But this is only to say that the superior article fetches the higher price. If we substitute 'clothes' for 'land' and say 'granted that clothes of a certain quality are to be had for nothing and are worth wearing, clothes of a better quality will bear a price equivalent to the superior satisfaction or service they would yield under the same circumstances,' we shall gain a certain point of vantage from which to examine the nature of the Ricardian hypothesis and the validity of the conclusions drawn from it; but we shall not have modified it in any way as a theory. If it is true theoretically and hypothetically of land it is true theoretically and hypothetically of everything; and even if it should turn out in any sense to have a superior degree of truth 'materially' when applied to land, it is only the more fatally misleading and confusing to announce it as 'formally' proper to it. And again, even to those most inclined to resent or at least to challenge this line of argument, it must at once be obvious that the Ricardian law of rent takes no account whatever of the distinction between inherent properties of the land and what it owes to the capital sunk in it, or the incidental advantages rising from the proximity of an industrial population. All these superiorities will tell in the rent demanded exactly on the Ricardian principle, so that the difference between economic 'land' and capital or advantages of situation is completely merged without in any way affecting the statement of the supposed 'law of rent.'

A diagram may easily be constructed in which different qualities of land may be represented along the axis of X and their supposed relative fertilities to a fixed application of labour and capital along the axis of Y. The 'marginal' land will occupy the extreme place to the right. A line parallel to the axis of X at the height of the 'marginal' yield will mark off in the area above it the total rent. This is not a functional curve; for the height of Y does not depend upon the length of X, but the units are expressly so placed on OX as to produce a declining Y. Any confusion on this subject would be equivalent to measuring off the altitude of the highest peak of the Himalayas on the axis of Y and then, above successive points on the axis of X, measuring the lesser heights, in declining order, of successive peaks till we came to Primrose Hill, and subsequently reading the diagram as a functional curve showing, say, some such relation as that between the height of mountains and their angular distance from the equator. There is a difference, then, between a descriptive and a functional curve, and what I have just described is a descriptive curve. It is applicable to land or to anything else of which typical units can be arranged in ascending or descending order of efficiency.

But the same figure has been used as a functional curve in connection with the theory of rent. Take a given fixed area of land of a certain quality and consider what would be its yield if it were 'dosed' with a certain quantity of labour and capital represented by a unit on the axis of X, and represent this yield by a rectangle upon this basis. Then add successive increments on the axis of X, and after a time you will have to represent the corresponding increments in the yield as declining. Go on till a further increment of labour and capital would not produce as large an increment in the yield of this land as it would if applied to some other piece of land of the same or different quality, or if turned to some non-agricultural business. The last increment actually applied is the 'marginal' increment; the increment it produces in the yield is by hypothesis adequate to induce its application, and therefore it measures the distributive share of a unit of it in the product. Draw at its altitude a line parallel to OX, and the rectangle represents the share of labour and capital, whereas the curvilinear surplus or residue represents rent.

I cannot stay to show that such a curve ought really to be made to pass through the origin, for though very essential to sound theory in general, this fact does not affect our present investigation. But, on the other hand, it is essential to dwell upon several other considerations. In passing I note again

that the whole argument is quite independent of the carefully drawn distinction between economic and commercial rent, or between land and capital sunk in land. But we must go on to still more important matters. It will be noticed that when we now speak of the 'marginal' increment, we are using the word in the sense of a 'differential,' as employed throughout our own investigation. It is not any peculiarity of the 'marginal' increment that makes it yield less than the others. It does not. They all have exactly the same differential effect on the yield, as to which none is after or afore the other. The height of this differential or marginal yield is dependent not upon the nature of each several dose, but upon their common 'quotality.' What we have here, then, is not a law or theory of rent at all, but the tacit assumption that the differential theory of distribution is true of every factor of production except land, and that rent is what is left after everything that is not rent is taken away. For observe, land-and-labour is treated as a homogeneous quantity, so that the reduction of heterogeneous factors to a common unit is assumed, and how is this to be done except by comparing their several efficiencies on the product, and so combining them as to keep those efficiencies in differential equivalence to their market prices, *i.e.*, their efficiencies on other land or in other industries? And thus the principle of marginal or differential efficiency as determining distributive share in the product has long been quite definitely, though naïvely and unconsciously, asserted in saying that the 'marginal'—in the sense of 'quotal'—efficiency of this compound factor of production, in the specified industry and out of it, will find the same level and will determine its remuneration.

This so-called statement of the law of rent, then, assumes our differential laws of exchange value and distribution, with all their implications, as ruling everywhere *except* in land and rent. As to rent it is, as we have observed, what is left when everything except rent is taken away. This can hardly be called a 'law,' but, such as it is, it is again common to all factors of production. Wages are all that is left when everything that is not wages is taken out. And this is actually the statement of Walker's 'law of wages.' And so with the rest.

But this is not all. In the treatment of rent that we are examining the differential theory of distribution is avowed with respect to every factor except land; but it is implied with respect to land also. This can be rigidly proved mathematically, as is now beginning to be acknowledged; and even the non-mathematical student can easily perceive that the forms of the figures representing the shares of 'land' and 'labour-and-capital' respectively are determined not by any peculiarity of land, but by the fact that land is supposed to remain constant, while labour-and-capital vary. But three pounds sterling applied to one acre is the same thing as a third of an acre coming under one pound's worth of culture, and five pounds per acre is a fifth of an acre per pound. Instead of taking an acre, therefore, and considering the difference of yield as two, three, four, five pounds are expended upon it, let us take one pound and consider the differences of yield as one-fifth, one-fourth, one-third, one-half of an acre come under it, or, in other words, as it spreads itself over these different areas. You will then find that you have a figure in which the same identical data are presented and the same identical results obtained, but the return to land is represented as a rectangle cut off by a line parallel to OX, and the return to labour-and-capital by a curvilinear 'surplus' or residuum. So that the supposed law of rent again turns out, in so far as it is true of land, to be true of all the other factors of production; but the unhappy confusion between the geometric properties of an arbitrarily selected constant factor in a diagram and the economic properties of land has brought dire confusion into economic thought and economic terminology. The Augean stables must be cleansed. We must understand that when the differential distribution is effected there is no surplus or residuum at all; and that any diagram of distribution that represents the shares of the different factors under different geometrical forms is sure to be misleading, and is likely to be particularly mischievous in its misdirection of social imagination and aspiration.

My last illustration shall be drawn from the dictum that rent does not enter into the cost of production. The value of all factors of production is derivative

from the value of the product. Neither rent, wages, nor interest properly *enter into* exchange value, for they all *come out* of it. Cost of production, as we have seen, means estimated productivity of agents in other industries; and to say that rent does not enter into the cost of production is to say that land cannot be employed and is not desired for any purpose except the one we are considering. Nay, on closer examination we shall find that it further implies that land has no incremental or differential significance at all, *i.e.*, that no one would cultivate more than he does if he could get it rent free.

Again, the fallacious argument, such as it is, will apply equally well to any other factor of production. If rent does not enter into the cost of production because wheat grown on land that bears a high rent, in consideration of its fertility, sells at the same price as that grown on land that bears a low rent, inasmuch as it is barren, then wages do not enter into the cost of production either, for wheat raised by labour that is well paid because it is efficient sells at the same price as wheat raised by labour that is ill paid because it is inefficient.

The whole conception depends upon the cost-of-production theory of value, and the 'marginal' theory of distribution, in the sense of the term which I have rejected. I am not attempting, at the moment, to refute either of those theories, but I am trying to show that if we reject them we must give up speaking as if we still held them.

These are but feeble, almost random, indications of some of the directions in which I think that convinced apostles of the differential economics should revise the methods of economic exposition. For myself I cannot but believe that if this were accomplished all serious opposition would cease, there would once again be a body of accepted economic doctrine, Jevons' dream would be accomplished, and economic science would be re-established 'on a sensible basis.'

It is impossible to exaggerate the importance of such a consummation. Social reformers and legislators will never be economists, and they will always work on economic theory of one kind or another. They will quote and apply such dicta as they can assimilate and such acknowledged principles as seem to serve their turn. Let us suppose there were a recognised body of economic doctrine the truth and relevancy of which perpetually revealed itself to all who looked below the surface, which taught men what to expect and how to analyse their experience; which insisted at every turn on the illuminating relation between our conduct in life and our conduct in business; which drove the analysis of our daily administration of our individual resources deeper, and thereby dissipated the mist that hangs about our economic relations, and concentrated attention upon the uniting and all-penetrating principles of our study. Economics might even then be no more than a feeble barrier against passion and might afford but a feeble light to guide honest enthusiasm, but it would exert a steady and a cumulative pressure, making for the truth. While the experts worked on severer methods than ever, popularisers would be found to drive homely illustrations and analogies into the general consciousness; and the roughly understood dicta bandied about in the name of Political Economy would at any rate stand in some relation to truth and to experience, instead of being, as they too often are at present, a mere armoury of consecrated paradoxes that cannot be understood because they are not true, that everyone uses as weapons while no one grasps as principles.

The following Papers were then read :—

1. *Trade Unions and Copartnership.* *By* Dr. CHARLES CARPENTER.

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2. *Trade Unions and Copartnership.* *By* JOHN B. C. KERSHAW.

The author in this paper discussed the statistics of the copartnership movement in the light of the facts and figures given in the latest Government report on profit-sharing and labour copartnership in the United Kingdom,[1]

[1] Cd. 6496, 1912.

and then dealt with the causes of past failures, more especially with the objections of the trades unions and their leaders to all extensions of the movement beyond its present limited field of application. The author's proposals for overcoming trades-union hostility were :—

1. Perfect freedom for all workers to join their respective unions if so inclined.
2. Recognition of trades-union rates of pay as basis of the copartnership scheme.
3. Election of selected labour leaders in each industry and locality as directors of large firms or companies.

The objections that might be raised to these proposals—by critics from both sides—were discussed in some detail, and the author expressed the opinion that the wave of unrest which is still troubling the industrial world in all countries will only be calmed and give place to more harmonious co-operation between capital and labour when the manual workers are given a larger share of the profits of industry and a greater stake than they now possess in the welfare and prosperity of their country.

Copartnership, in the author's opinion, is the most simple and effective means for bringing about this change in the organisation of our industries, and at the same time preserving that efficiency of financial and technical control, without which no industry can succeed in these modern days. Past failures in the attempts to run industries entirely by working-men for the workers' own benefit have proved the need for a closer co-operation between Capital, Brains, and Labour. There are three essentials required for the successful conduct of modern manufacturing industries : (1) A plentiful and cheap supply of capital; (2) a plentiful supply of skilled and contented labour; (3) skilled technical and business management which can take instant advantage of all opportunities offered for improving the manufacture and of extending the market for the finished goods.

The copartnership principle is the one which offers the best chance of attaining these three conditions of success, and if trades-union hostility to the principle could be disarmed the movement would extend with amazing rapidity.

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3. *The Scientific Study of Business Organisation.* *By* Professor C. H. Oldham.

Faculties of Commerce in our universities are designed to provide university education mainly for the Employer Class, the persons who are to control and direct business enterprises. In their programmes of studies an important place should be allotted to the scientific study of modern Business Organisation. Apart from this purely educational value, the study has great practical importance from wider standpoints, viz. : (i) the profitable development of large-scale business in British industry and commerce, and (ii) the application of economic science to the changing structure of business under modern conditions.

The paper pointed out how this branch of study suffers in these countries from a lack of authentic material in the form of analysed examples of actual business organisation based on British practice and experience. At present we have to look to American business men and to American universities for guidance in this study. This position is unsatisfactory : for American business organisation and practice differ in some important respects from British organisation and practice, and the interpretation of this difference is itself a curiously interesting economic problem. The writer advocated concerted action to procure the required materials from the actual working organisations of typical British businesses.

Modern Business Organisation, as a subject for study, includes the following five branches, viz. : (*a*) Forms of the Business Authority, classified into types by noting the way legal responsibility is fixed, with the merits and limitations of each type. The controlling authority undergoes transformation into new forms as the scale of the business grows larger. (*b*) The internal Industrial Organisation of the individual business. The proper Location, Lay-out, and Equipment of the plant. This establishes a departmental organisation and inter-relation for each step in the movement of a product through the factory from raw material up

to finished units of output. (c) The internal Staff Organisation of the individual business. There is not merely a division of labour, but a division of function and a sub-division of authority. This sets up a departmental organisation and inter-relation from the head management right down to the last man who is to be possessed of authority. (d) Forms of Combinations between many individual firms, in order to regulate or to restrict competition: the descriptive side of what is loosely called the 'Trust Movement' in industry. (e) Modern institutions organised for handling questions in dispute between Employer and Employed: such as Trade Unions, Employers' Federations, Conciliation Boards, &c.

Of course, Business Organisation stands to Business Policy very much as Anatomy stands to Physiology: the one is structure, the other function. The study of both, in their general principles, is essential to the Higher Commercial Education. But this paper is concerned with the former only.

The central problems of Business Organisation have to do with Staff Organisation and the sub-division into departments. The scientific clue to departmental division lies in the practical fact that different stages in the making or the marketing of goods require widely diverse experiences in the authorities that control those stages. In any properly organised business it is possible to exhibit by a chart on paper the departmental divisions in such a way as to show how the authorities governing different departments are related to the industrial body as a whole; in other words, to show exactly where each authority is related to the others, and how far each authority may extend in the business.

Now, we can find in American text-books the Organisation Charts of many different types of business; for examples, an American railroad company, a large meat-packers' business, a shipbuilding yard, a typewriter (or motor-car) manufacturing company, &c. One learns from them that, while all factories are not alike, the principles of the accounting system used by one are applicable to another: the details may vary, but not the principles. Any business man, by following a similar analysis, can put down on paper the actual, or ideal, Organisation Chart for his own special business. This chart will express all the mutual relations governing the organisation of his business; it will show clearly the very foundation upon which all the authorities, the accounting system, and the business operations are based and conducted. But the grand impediment to the study of Business Organisation in this country is the complete absence from our text-books of Organisation Charts stating the actual facts of the working organisation of representative British businesses of various types and dimensions. It is well known that large-scale production ceases to be profitable when its organisation becomes unmanageable: the limit to the size of the business-unit is fixed by the ability for administration. But this ability can be greatly extended by the scientific study of Business Organisation.

The paper was illustrated by lantern slides showing the Organisation Charts of various types of businesses, and the method of analysing such charts when problems of business administration raise fresh issues in Business Organisation.

FRIDAY, SEPTEMBER 12.

Discussion on Inland Waterways.

(i) *The Improvement and Unification of English Waterways. By* Lord SHUTTLEWORTH.

The author recalled the circumstances under which a Royal Commission was appointed in 1906 to inquire into the inland waterways question in the United Kingdom. After four years' labours, they reported on English Waterways, contrasting their disunited and unimproved condition with the results of unification and improvement of this system of transport in foreign countries, and recommending the appointment of a Central Waterway Board to deal with Waterways, much as the Road Board deals with roads, without undertaking the business of carrying.

The Commission had done its part, and it now rested with the traders and

their organisations to press the recommendations on Parliament and the Government, in the form of step-by-step improvement—first, the formation of the Waterway Board; secondly, unification; and, thirdly, the first instalment of improvement of one or two of the main routes of waterways. To answer doubts, he pointed to the present obsolete condition of our canals, and the undeveloped state of our rivers, as well as the fact that we have a fine network of connected waterways in England, but remaining unimproved since 1830, in contrast with those in Northern France and Southern Belgium, where the results of unification and improvement, during recent years, should be visited and studied, as well as the statistics of increase of waterway traffic, accompanied by simultaneous increase of railway traffic also. In England, not only would the railway traffic be similarly increased by the development of the output of inland factories, thanks to a cheaper transport of raw materials, &c., but the transfer of industries to the coast and subsequent loss of railway rates would be arrested.

After quoting from the anticipations of the Commission of indirect return on the probable cost of unification and improvement, in the shape of benefit to trade, he pointed out that the perseverance of France, Belgium and Germany year by year in the policy of waterway improvement proved that experience had convinced foreign Governments of the benefit to trade resulting from waterway reform and extension.

(ii) *Some Reasons why the State should improve the Canals and Waterways of the United Kingdom. By* Sir JOHN PURSER GRIFFITH, *M.Inst.C.E.*

The object of this paper was to encourage discussion on some of the economic reasons which appeared to the writer to warrant State interference for the purpose of improving the canals and waterways of this country. The writer, as an engineering member of the Royal Commission on Canals and Waterways, signed the majority report without reservation, because from an engineering point of view he was satisfied that the proposals were reasonable and practicable, and also because on economic grounds the proposals appeared to him sound. He thought it would scarcely be reasonable for him to take up time by entering into detailed descriptions of the engineering difficulties to be overcome, but he wished to say that many of the objections which have appeared in print to the proposals to develop the waterways of Great Britain were difficulties conjured up by the writers, and have no foundation in the proposals of the Royal Commission.

While aiming at the formation of trunk waterways of the 100 tons and 300 tons standard, the aim was ever present in the minds of the Commissioners that the existing type of canal boat and barge must be provided for, and that the new locks and lifts should be designed so as to allow the passage of trains of these boats and barges, and permit of the economic introduction of mechanical haulage. 'There would be no scrapping of canal plant,' to use the expressive words of the explanatory pamphlet issued by the Waterways Association.

The writer has been impressed with the future possibilities of our waterways, because an extensive system of inland navigation exists in the country, represented in Great Britain and Ireland by 4,670 miles of canals and navigations, which were constructed as independent concerns without any idea of forming a united scheme or system of inland navigation, and which generally speaking are in no better condition than they were eighty years ago; yet in the face of such hindrances many of these waterways are still worked with advantage to certain districts and trades.

The principal opposition to the revival of inland navigation by the aid of public funds comes from those who profess to speak in the interests of the railway companies, or from economists who believe that public money should not be used in aid of waterways in competition with railways constructed by private enterprise.

There exists, however, a class of railway proprietors who believe that railways would be benefited by a transfer of a large volume of low-class traffic from rails to water, and that the present inflated railway capital might be used

to better advantage for higher-class traffic. An examination of the Railway Traffic Returns issued by the Board of Trade would seem to support this view.

When speaking of the State ownership of waterways, it should be borne in mind that one of the recommendations of the Royal Commission was, that, although owners of the waterways, the State should not become carriers on these waterways. These water highways would be open to all carriers, whether private individuals or public companies, and it is reasonable to believe that the railway companies, who are amongst the most efficiently organised carriers, would be amongst the first to take advantage of the improved waterways.

The question of State ownership of canals and waterways, or of financial aid by the State towards their revival, is one on which great difference of opinion still exists. The passing of the Development and Road Improvement Funds Act shows, however, that a great change is coming over public opinion on such matters. The improvement of communication by road is becoming year by year of increasing public concern, and in like manner it appears probable that interest in inland navigation will develop as the need for increased transport facilities is felt. The advances in motor traction or haulage ashore and afloat will hasten progress.

The Manchester Ship Canal furnishes an example of waterway construction started as a private enterprise which probably would not have been completed but for the public spirit of the Manchester Corporation in raising 5,000,000*l*. in aid of the work on the credit of the rates of the city. No one can now deny the advantage this work has been to Lancashire, and yet the financial loss to the original shareholders has probably done much to stop the improvement of canals and waterways by private enterprise.

(iii) *The Waterways of France, Belgium, and Germany.* *By* Frank R. Durham, *A.M.Inst.C.E.*

This paper dealt in a short, cursory manner with the following points of interest, quoting freely from the Final Report of the Royal Commission of Canals and Waterways, and Sir William Lindley's report on the Foreign Inquiry to the said Commission:—

(*a*) The reasons for the development of the waterway system due to economic development of the resources of the countries.

(*b*) Distribution and standardisation of the waterways.

(*c*) Ownership of the traffic conditions and facilities in the three countries. Ownership of the inland harbours.

(*d*) Administration of the waterways.

(*e*) Organisation of the towage and the tendency towards State administration.

(*f*) Expenditure on waterways and networks.

(*g*) Means of raising capital, methods adopted in the three countries, and the principle of local contributions, or contributions from interested persons.

(*h*) Traffic. Development of traffic since the modernised development of the waterway systems.

(*i*) Comparison. A short comparison with England, quoted from the Final Report of the Royal Commission on Canals and Waterways.

(iv) *Inland Waterways in England.* *By* R. B. Dunwoody.

(v) *A Forward Canal Policy: Its Economic Justification.* *By* W. M. Acworth, *M.A.*

The object of this paper was to show that canals as a means of transport are necessarily and inherently inferior to railways; that canals cannot carry cheaper than railways if the total cost of carriage is taken into consideration; that canals can only compete with railways if, as in France and in Germany, the competition is subsidised and a large part of the cost of canal carriage laid on the shoulders of the taxpayer, and that therefore a forward canal policy has no economic justification.

The writer pointed out that in England, where canals and railways have

been left to compete on equal terms, the canals have been definitely beaten; that in America the bulk of the canals have been abandoned, and even the Erie Canal, though maintained as a free highway at public expense, has lost all its old importance; that in France, not only are the canals free highways maintained at public expense, but the railways are forbidden to reduce their rates to the canal level, and still the average total ton mile cost is higher on the canals than on the railways.

From Germany figures of the important Dortmund-Ems Canal were given to show that its construction has resulted in an economic loss to the State, and only a small gain to the individual trader.

It was pointed out that canals are necessarily inferior to railways as a means of transport, because (*a*) their capital cost is higher, (*b*) their carrying capacity is smaller, (*c*) they only cater for low-class goods, in bulk, and (*d*) they can only reach the ultimate point of production or consumption by the supplementary use of waggons or railway trucks.

It was also pointed out that the traders and localities for whom canals are potentially available naturally have an interest in promoting their construction at the public expense, as thereby they, paying only a proportion of the total cost of carriage, throw the remainder of that cost on the public at large, and so not only reduce their expenses, but obtain a differential advantage over competitors to whom the railway only is accessible.

The writer concluded that the adoption of a forward policy cannot be justified as in the interest of the community at large, and that therefore it lies upon those who urge the adoption of such a policy in any individual case to prove their right to secure for themselves a differential advantage at the cost of the whole community.

MONDAY, SEPTEMBER 15.

Discussion on Prices and the Cost of Living.

(i) *The Relation between the Changes of Wholesale and Retail Prices of Food. By* Dr. A. L. Bowley.

Between wholesale and retail prices come the expenses and profits of merchants and brokers, of transport, of manufacture, of taxes, of interest and of retail dealing. It is not known in general whether these expenses tend to vary with the movement of wholesale prices or remain stationary. If the former, retail prices would vary proportionately with wholesale; if the latter, retail prices would move less per cent. than wholesale. The question is examined by comparing the prices of grain, flour, and bread month by month during 1906–1913. Two measurements are proper to make: (1) The coefficient of correlation, which shows how closely the two prices are casually connected; (2) the standard deviations, which show how far the prices diverge from their average. If the cost of distribution and manufacture remained unchanged, the ratio of the standard deviations of wholesale and retail prices would equal the ratio of the retail price to the wholesale price of the same unit. This is found to be the case with bread and flour, so that

$$\text{The price of a quartern loaf} = 2{\cdot}27d. + 3{\cdot}33d. + \frac{\text{Price of flour per cwt.}-11s.}{\text{Number of loaves made from cwt.}}$$

where $3{\cdot}33d.$ is the cost of the flour, and $2{\cdot}27d.$ the cost and profit of baking.

The same process is applied to the wholesale prices in 1896-1910 of bread, flour, beef, mutton, bacon, butter, potatoes, sugar, tea, eggs, and cheese, as compared with the London retail prices stated in the publications of the Board of Trade. The commodities are weighted in the proportion in which they cur in a town workman's expenditure, and together they account for over thirds of the expenditure on food. No uniform relation is found, but all are grouped together the following equation is satisfied :—

$$\text{of budget} = \text{Wholesale price of goods (10}s.) + \text{Cost of distribution (5}s.) + 1{\cdot}11 \text{ of excess of wholesale price over 10}s.$$

This relation corresponds to a percentage movement of retail prices equal to three-quarters of the percentage movement of wholesale prices. Column A in the following table shows the movements of the wholesale prices of the goods selected; Column B the movement of retail prices from this equation; Column C the movement on the hypothesis that cost of distribution remains unchanged; Column D the weighted average of the Board of Trade's index-numbers for the same commodities, the numbers in brackets showing the effect of subtracting the tea and sugar duties from retail prices. Column E gives the Board of Trade's number for London including all food.

—	Price Movements on Various Hypotheses			*Quinquennial Averages.*	
	A	B	C	D	E
1881–2	132	123	121	—	—
1883–7	112	108	107	—	—
1888–92	104	102	102	—	—
1893–97	93	94	95	91½ (93)	91½
1898–1902	97	97	98	97 (97½)	96½
1903–7	100	100	100	100 (100)	100
1908–12	111	107	107	107½ (107½)	106½
1913	113	109	108	—	—

It is suggested that retail measurements are in some cases so uncertain that it is necessary to explain and harmonise such differences as are shown between Columns C and D before either can be used as minutely correct, and that it is not improbable that the figure even in Column C for 1893–7 is too low.

(ii) *The Construction of Index Numbers to Show Changes in the Cost of the Principal Articles of Food for the Working Classes. By* MRS. FRANCES WOOD, *B.Sc.*

At present the only food index numbers published annually are those given for London by the Board of Trade in their 'Abstract of Labour Statistics,' but as no information is given as to the data, methods, &c., used in their construction, it is impossible to judge whether they are trustworthy. In spite of this they are almost universally quoted as applying not only to London but even to the United Kingdom as a whole!

Weekly or monthly records of the prices charged by retailers for the principal articles of food are very much to be preferred to records of the prices paid by consumers, *i.e.*, family budgets, as data upon which to base food index numbers, and, if the results are to be taken as applying especially to the working classes, the records should be obtained, if possible, from working-class firms. Family budgets must, however, be obtained to give the articles commonly consumed by the working classes as well as the relative importance of the different articles.

Series of index numbers for bread, prepared by the author from the returns of seven large London firms, show that the prices charged even by those firms which deal with the same class of customer do not show similar variations from year to year, and point to the conclusion that reliable index numbers for a given town can only be obtained from the combined returns of a number of firms.

The kind of the commodity studied can and must be kept constant during the course of an investigation, *e.g.*, Australian mutton one year must not be compared with English mutton the next year. But the quality of Australian mutton, for example, may vary from year to year, so that the actual quality of the article studied will not necessarily be kept constant. Since, however, the investigation is concerned with changes in the cost of living, it is doubtful whether the index numbers need be modified on account of such changes in quality only. In the case of commodities such as butter and eggs, especially among working-class firms, no practical attempt is made to differentiate between the different kinds. It is accordingly impossible to follow changes in the price of any individual

kind, but the change in the price of either all the kinds sold or possibly of the cheapest kind sold may be taken as a criterion.

Commodities such as meat and bacon present special difficulties, as here the consumer can purchase a variety of cuts. In this case the most reliable index numbers will probably be obtained by studying the change in the price of all joints or cuts.

Finally, the index numbers of the various commodities must be combined to form general index numbers, the different commodities being weighted according to the extent to which they enter into the consumption of the average working-class family, as shown by the investigation of a number of family budgets.

(iii) *The Industrial Credit System and Imprisonment for Debt.* *By* W. H. Whitelock.

This paper dealt with the following matters :—

The various systems on which goods are sold on credit to the working classes by industrial traders in Birmingham—provision dealers, general merchants, Scotch drapers, furniture dealers. The hire-purchase system and the various articles supplied under it. The public misconception about moneylenders. The various classes in this trade. The terms on which working men can borrow in Birmingham, and the extent of their transactions. The proportion of cases in each class of trade which cannot be collected without the assistance of the court. Court procedure. The difficulties in the way of effecting service of process. The investigation of defendant's means at the hearing, and the principle of the instalment order. The methods of enforcing payment—(1) Execution against goods, and its disadvantages; (2) Debtors Act, and the suspended commitment order. The causes of working-class insolvency, and the relief given by the administration order. Its distinction from the ordinary bankruptcy. The results as far as creditors are concerned. The Committee on Imprisonment for Debt and its recommendations—their injustice and impracticability. The objection to the abolition of imprisonment. The real grievance of the Debtors Act, and its remedy by improved methods of administration. The system adopted in Birmingham to this end, and its results as compared with other districts.

(iv) *The Economic Value of Foodstuffs.* *By* Professor Leonard Hill, *M.B., F.R.S.*

(v) *What an International Conference on the High Cost of Living would do.* *By* Professor Irving Fisher.

A movement for an International Conference on the High Cost of Living has been active for the last two years. It has received the support of the President and ex-President of the United States, the President of France, and many high officials of other countries, such as England, Canada, Germany, Austria, Italy, &c.

If such a Conference is called it will discuss and formulate the problems which need solution and refer them to committees appointed for the purpose of investigating them and reporting later to the Conference. These problems fall under five heads: problems of fact, of causes, of past evils, of future prospects, of remedies.

Under the first head (facts) will come a study of the most suitable form of index numbers and the most suitable list of commodities to be included in these index numbers. Such an investigation should enable us to know with considerable precision the rise of prices in different countries and possibly also the relative height of the present price levels of those countries.

Statistics of price levels are equivalent to statistics of the purchasing power of monetary units. But the studies of the Conference should include, besides the purchasing power of monetary units, the number of monetary units in our incomes—particularly in wages.

The second branch of our problem (causes) takes us into a more difficult

field. According to the writer's understanding of this problem the question of the causes of rising prices is a question of the rate of increase of the means for purchasing commodities as compared with the increase in the volume of trade in these commodities. This study resolves itself into a study of five principal factors, namely, the amount of money in circulation, the velocity of its circulation, the amount of deposits subject to check, their velocity (or activity of turnover), and the volume of trade. Some actual statistics for these five magnitudes are available in the United States, but none for other countries. There are, however, some indications which show the relative rate at which these various magnitudes are increasing in the world as a whole.

The great conflict of opinion at the Conference will doubtless be as to whether the rise of prices means an inflation of money and credit or a scarcity of goods. If the result of its investigations should indicate that the rise of prices is chiefly a monetary phenomenon, this would indicate the importance of a monetary remedy, such as some plan for 'standardising' monetary units, *i.e.*, 'stabilising' the general level of prices. But whether or not any such far-reaching remedy can be applied or even recommended, there are other and less ambitious remedies in the way of saving waste which ought to be carefully considered. Such, for instance, are the conservation of natural resources, the elimination of unnecessary middlemen, the introduction of co-operation where economies can thereby be effected, the improvement of banking systems, the removal of high tariff walls, &c.

The outlook seems to many of us to indicate that the rise in world prices is permanent and likely to be aggravated in future years. Under these circumstances, even though we cannot immediately apply remedies for lack of sufficient agreement, the sooner we can secure the necessary data to lead to such an agreement the better.

TUESDAY, SEPTEMBER 16.

The following Papers were read :—

1. *The Economic Order. By* Professor J. H. Muirhead.

I. Economics is probably alone among the sciences recognised at the British Association, in having not only its particular conclusions, but the whole field and method of its work, questioned at the present time. This suspicion is not confined to the refined Anarchism of Tolstoi. It is shared by current Socialism and nearly the whole body of intelligent working-men who 'have no need of the economist.' It is reflected in a certain 'loss of nerve' among economists themselves, many of whom claim no more than 'historic' value for their conclusions.

To combat this suspicion effectually and establish the legitimate authority of economic science it is not sufficient to appeal from mechanical to biological conceptions, from 'individual' to 'crowd psychology' (art. 'Economics' in 'Ency. Brit.,' 1910). This can only introduce new confusion. Nor is it sufficient to refer generally to the 'abstractness' of the conclusions of the earlier economics. We want to know definitely what they are abstractions from, and what remains when we have allowed for the abstractions. This we can only do in the light of a truer philosophy of the individual and society.

II. This is not the place for a sketch of such a philosophy. But the central point can be made clear. The whole question turns on the nature of selfhood or individuality. Individuality depends not, as in the old philosophy, on the exclusiveness of persons, but on the possession and adequate performance of a social function. To *have* a self or a soul is to have a 'place' in the whole. To *be* a self is to give oneself to a whole. But to admit this seems to traverse the economist's assumption of forces essentially self-centred (if not selfish), and of a permanent order, founded on their dominance in the aggregate. Hence the 'antinomy' making the present problem. The principle on which the solution of it must be sought is that *an element which in itself has no independent value may survive as an essential factor in a whole, as a line or a colour meaningless*

in itself survives in a picture. The exclusivéness of the self, though it has no finality, is yet an indispensable phase of its life.

(*a*) A world of commensurable values necessarily springs up as the result of man's 'necessities' as a finite being, the value of each individual being primarily measurable by his contribution to this world of values—by 'what he is.' To deny is again to abstract.

(*b*) In this world division of labour and exchange of products are necessary economies—the revolt against this in itself (*e.g.*, in H. G. Wells) is reactionary—and this involves competition between buyer and seller—the one guided by need of the product, the other by need of 'remuneration' (ultimately his continued efficiency as a producer).

(*c*) At any given stage markets and 'places' are definitely limited—the possible applicants are indefinite; giving rise again to competition between the sellers of the same article—goods or powers.

The new philosophy comes not to destroy, but to fulfil; but the justification is not to be sought in the 'rights of the individual,' but in social well-being, which requires :—

(i.) That everyone shall make himself of economic value.
(ii.) That needs shall be supplied in the most economical way.
(iii.) That the right man shall have the right place.

The social problem is not therefore to be solved by ignoring or superseding this order, but by subordinating it to the wider ends of life, *e.g.*, by the care of the industrially weak or unfit; the abolition of monopolies other than those which, like talents, represent intrinsic power of contributing to social values; protection against other forms of exploitation. For the rest there is no antagonism between the effects of competition and social organisation and individual well-being. The acquisition by personal effort on the part of the individual of industrial skill is the condition of acceptance by a protective organisation, *e.g.*, a trade union; the most important condition of the happiness of a society of finite beings is that each should have the place suited to his powers.

III. The general conclusion as to the work of economics : while it has nothing to do with ultimate ends, and cannot therefore prescribe laws for human life as a whole, or claim a place for its ideals where the 'economic' order is of necessity superseded by deeper organic relations, as in those of husband and wife, yet the more the importance of the material basis of civilisation and of men's occupations in contributing to it comes to be recognised, the more value will be set on its researches. More particularly in the present time of the re-organisation of industry, with a view to the vindication of a truer individuality, do we want to know how the special changes advocated in their name—the minimum wage, the lengthening of the school period, modified forms of protection, the strengthening of the economic position of woman, industrial training, &c.—will affect the economic order as above described.

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2. *Qualifications of Diminishing Utility.* *By* W. R. Scott, *M.A., D.Phil., Litt.D.*

A principle of increasing utility can be established from (1) the general experience of the race; (2) from actual instances; (3) deductively from the nature of desire.

As a result of these inquiries it becomes possible to escape from the atomistic treatment of motives, considering a system of desire or scheme of consumption rather than the postulate of a separate want for each distinct commodity. The extent to which this synthesis should be extended. Applications of the new theory to taxation should be made cautiously. It has advantages for the general theory of political economy, in extending its symmetry, in removing its pessimism, and in bringing a reconciliation with poetry, philosophy, and art.

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3. *How far are Mathematical Methods really of Use in Economic Science? By* A. J. KENNY, *M.A.*

The object of this paper was to consider the methods and principles involved in the numerous applications of mathematics which have been made to economic science. A distinction was made between the algebraic method, with extension to calculus, as used by Cournot and others, and methods which are not wholly of a mathematical nature, but in which mathematics are used to support some particular doctrine, as, for example, that of marginal utility. In the latter group the question arises whether these abstract conceptions are adequately represented by the mathematical symbols used, and consequently whether the conclusions drawn are valid.

It can be shown that on account of the restrictions imposed on the mathematical method, and the consequent lack of variety in the methods employed, many points are unnecessarily obscured. For instance, the principle of maximum and minimum is sometimes applied in the theory of demand and the conclusion arrived at that the price is in the ratio of the marginal utilities of the commodity and money. This determines the quantity purchased, if the marginal utility of money be known, as is usually assumed. A general method, however, leads to the conclusion that the marginal utility of money depends essentially on its distribution in the purchase of all the commodities desired, so that the application of mathematics, subject to the hypothesis that the utility of money is known, leads to a result which is only true in a limited sense.

Again, in support of the assertion that the problem of economic equilibrium is determinate, equations are found which are equal in number to the unknown quantities. As the equations so found are not in general of the first degree, there may be a large number of possible solutions. This shows the necessity of recognising conditions which are not capable of being expressed as relations between variables.

The conclusion was that mathematical methods are capable of throwing light on economic problems in a manner impossible by any other means. But in order that valid results may be obtained it is necessary that the methods used should be of such a general character as to admit of the possibility of discussing various hypotheses.

4. *Some Effects of Compulsion on the Economics of Sickness Insurance. By* SAMUEL F. WILSON.

The Insurance Act of 1911 has introduced many new and important elements into the economics of the State, the employer, and the wage-earner. The limited part of the general subject dealt with in this brief paper was the effects of compulsion on that part of the scheme—about one-third of the total contributions—which is devoted to the payment of sickness benefits.

Regarded from an economic point of view, this part differs from the other portions of the scheme, inasmuch as a flat rate of contributions is fixed to meet contingent and gradually increasing benefits, thus necessitating large reserves of capital, and periodical valuations of the present values of contributions and benefits. Into this part of the scheme, but more especially under compulsion, the great variety of human nature, as well as of circumstances, enter in many ways.

Hitherto these valuations have affected voluntary members only, so that secession has always opened a safety valve for dissatisfaction. Under compulsion this valve is closed, and deficiencies when disclosed, as they certainly will be, will have a much more disastrous effect.

It is submitted that a part of the task of unravelling the new and complex conditions affecting solvency might very well be undertaken by this Section of the British Association. In time the conditions imposed by compulsion become the normal field for voluntary effort, and it is highly desirable that such conditions should be thoroughly investigated. A strong critical element outside the Government actuarial office, and altogether apart from the make-believe of politicians and political writers, gives promise of the best and most enduring results.

WEDNESDAY, SEPTEMBER 17.

The following Papers and Reports were read :—

1. *Some of the Economic Effects of the Panama Canal. By* Professor A. W. Kirkaldy.

In estimating the probable economic effects of the opening of the Panama Canal there must be noted :—A. Local effects; B. the effects on world trade.

From the industrial point of view three questions arise :—(i) who shall supply certain markets: (ii) who shall perform the service of transport: (iii) what routes shall the shipping take?

The following are among the principal factors on the balance of advantages of which the above questions will be decided : 1. distance; 2. tolls on the route; 3. freights, and the possibility of continuous freight earning; 4. fuel stations; 5. insurance rates; 6. the political factor; 7. rates of exchange; 8. investments of capital and banking facilities; 9. the human factor--manufacturing and commercial ability, experience of trade and markets, present possession.

A. *Local Effects.*—The Canal will add enormously to the commercial facilities between the various regions of the American continent and the adjacent islands, hence important developments may be expected. The West India Islands will enter upon a new period of prosperity, especially when the internal-combustion engine takes the place of steam, and oil replaces coal. English business and fiscal methods will have a great effect on making the West Indies important to shipping, and thus assist the development of local industries, especially the export of raw material. The comparatively unprogressive States of Central and South America will undergo remarkable developments owing to increased immigration of Europeans and increased trade. These local benefits will be the chief, and ample, justification for the construction of the Canal.

B. *The Effect on World Trade.*—1. America realises the importance of the coal trade to the United Kingdom; there will be a strenuous attempt to displace British coal throughout the world in order to give American shipping the advantages at present enjoyed by British. If successful this will deal a mortal blow at our Mercantile Marine. Thus the British coal industry must realise the situation, and both the capital and labour interested resolve to hold the markets at all costs until the fuel question—coal or oil—is finally settled.

2. The published scheme of tolls which frees American coasting ships raises an international question. If the Canal be worked on business principles, higher tolls will be exacted from other shipping; this will either cause a grievance, or decrease the tonnage using the Canal. The question might be made domestic instead of international if America charged equal tolls to all, and gave bounties to such shipping as it wishes to favour.

Factors.—1. *Distance.*—Effects on Australasian and Far Eastern markets will be considerable. The mileage run by a steamer is a serious factor in cost of service. In this shipping offers a contrast to railways, for when trucks are loaded, length of haul has but little effect on cost of service.

Taking London and New York as the typical European and American ports, the markets of the world fall into three classes :—(1) Countries in close proximity to the Canal: here the effect will be greatest and, in many cases, the use of the Canal a necessity. (2) Australasia and the Far East. At present there is a choice of routes to these markets; Panama will offer another alternative. (3) Ports not directly affected.

Class 2 is receiving most attention from those estimating the effects on world trade. There is a parallel equidistant from London *via* Suez, and from New York *via* Panama. On the South Coast of Australia this is Port Lincoln, Adelaide being the nearest great port. All Asiatic ports west of Japan will continue to be nearer to London; *e.g.*, Manila will be 2,000 miles nearer. But all Japanese and New Zealand ports and all Australian ports east of Adelaide will be nearer New York. If it costs 2*s.* to transport one ton of goods 1,000 miles, distance saved will give American manufacturers an advantage of from

2*s*. to 7*s*. 6*d*. per ton on all goods supplied to ports between Melbourne and Wellington, N.Z.

2. *Tolls*.—Panama differs from Suez here. Suez had an immediate monopoly; with Panama there is in many instances a choice of routes, and high tolls will deflect tonnage.

3. *Freights*.—To benefit American shipping freight must be available both out and home. To benefit American manufacturers freights must be low. At present Europe supplies Australasia with manufactured goods, and the shipping goes *via* Suez. This route gives a maximum of trading possibilities and great facilities for coaling. The Cape route, too, offers to fully loaded steamers the advantage of cheap bunker-coal. For the homeward voyage from Australasia a partly loaded steamer goes *via* the Horn to pick up cargo at ports like Monte Video. The Canal would not attract these ships. When Panama is open will all-round-the-world services be organised? Great Britain is in a better position to do this than any other country. The rumours current recently that an existing shipping combine was trying to arrange an amalgamation with one of the oldest Far Eastern shipping companies were probably due to the hope of being able to commence such a service, having some of the chief trades of the world as tributaries, from the moment that Panama is available. America hopes to open up new markets, *e.g.*, wool. This now concentrates at London, but there is a tendency towards decentralisation, and if America develops the woollen industry, she will get a wool market without necessarily constructing a Panama Canal.

4. *Fuel Stations*.—This will be one of the decisive factors, and lead to the keenest commercial rivalry. The American Government are planning to supply good coal at either end of the Canal at 19*s*. per ton. The English coal on the Suez route is at present much dearer; to maintain the Suez route in its integrity the supply of cheaper coal is a necessity. When oil replaces coal the British Empire resources will be ample to maintain our commercial position, but this must not in the meantime be placed in jeopardy, or disaster may ensue.

5. *Insurance Rates*—will probably be the same on both routes.

6. *The Political Factor*.—The working of the Imperial ideal in Great Britain, America, and Germany should be noted.

Preferences granted by the Dominions have materially assisted British trade. The possession of the Philippines has displaced Spain from the position of chief trader there in favour of America. The importance of this factor can be traced in the case of Japan, and China, when settled government comes, will be another notable instance.

7. *Rates of Exchange*.—The Far East has a silver, Europe and America a gold, standard. Rates of exchange affect trading relations. The whole question should be carefully studied. About seven years ago, when a Chinese merchant could get exchange on the west coast of America at the rate of 119 taels for $100 gold, it paid him to import thence timber and flour; but at present rates, namely, 160 taels for $100 gold, this ceases to be profitable business, and he can trade to greater advantage locally. This factor works independently of trade routes.

8. *Investments and Banking*.—Great Britain is a great creditor nation. Her advances have been really made in goods, and though the interest has to be paid in gold, it comes in goods covered by bills in terms of sterling, so that investors get their interest in gold. The British, too, have banking establishments all over the world. London is the great settling-place for international trade. All this gives England a very great advantage. Germany has followed England in this. Finally, the Englishman is, roughly speaking, the man in possession, and though at one time he seemed somnolescent, at present he is very wide awake. He has many advantages: (i) for the transport services; cheap, economically worked ships, carefully organised trading facilities throughout the world, and the knowledge and experience which enable him to retain old trades and be the first to enter new ones. (ii) So far as retaining the markets for manufactured goods is concerned he has an unrivalled labour force endowed with hereditary skill, he can get the pick of the raw material, thanks to his knowledge of markets, and a fiscal policy which favours England as a buyer of raw and semi-manufactured materials; finally, British goods are

known all over the world for their quality. Honest goods and honourable dealing on the part of the seller are their own market.

In conclusion, the economic effects of the route can be easily exaggerated. So far as the outside world is concerned, the greatest effect of the opening of the Canal will probably be to get commerce and trade out of a groove, and cause an all-round modernisation of business methods. The old will have to be scrapped, friction among the factors of production will have to be eliminated, capital and labour in competing countries will have to learn to work harmoniously together.

Socially and economically this will effect a very great result. Is it what America dreamed of when she entered upon this stupendous undertaking?

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2. *English Town Development in the Nineteenth Century.* *By* F. Tillyard.

During the century the main social problem changes from a rural to an urban problem. Is there a single or a dual movement in the urban centres? View of the 'majority commissioners.' When did the separation of upper and lower working-class begin? The physical separation is based on desire for healthier physical surroundings.

1800–1830 *period.*—Sanitation of the period; legislation by Private Acts of Parliament examined for various towns; administration (especially in regard to the drink traffic) and its moral effects.

1830–1870 *period.*—Enormous growth of urban population; housing policy of the period; back-to-back houses; no general improvement in death-rate; the change in licensing policy and ante-1869 beerhouses; evidence of present-day survivals from this period; the Private and General Adoptive Acts of the period; minor legislation and administrative successes.

1870–1900 *period.*—The legislation of the seventies opens a new chapter; its importance for the future and its failure in existing districts; difference between 'slum' and 'industrial suburb,' mainly pre-1872 and post-1872; this legislation at work in three types of towns exemplified by Birmingham, Leicester, and Middlesbrough.

Is special legislation needed for the pre-1872 districts? Should the general standard of sanitary legislation be raised?

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3. *Human Geography and Industry Planning.* *By* C. R. Enock, *F.R.G.S.*

The author submitted that the economic problems before the world at the present time call for the establishment and exercise of a comprehensive and constructive science, whose aim would be to evolve and teach the principles under which economic equilibrium in the life of communities may be attained. It was argued that the real science of living on the earth, or 'human geography,' the adaptation of natural resources and national potentialities to the life of the community, has never been formulated. The congestion of the population in towns, the desertion of the countryside, the high cost of living, low wages, unemployment, and so forth, are related phenomena, intimately connected with the conservation and development of natural resources. The axiom was advanced that the world is capable of supporting all its inhabitants in sufficiency, and its failure to do so is due to the non-emergence so far of an organising science, whose deliberations would be aloof from egoistic or partisan influences. It was affirmed that the teaching and operations of such a science is necessary if social security is to be maintained and civilisation advanced; and it was suggested that to give effect thereto an institution should be established which would bear the same relation to the science of living as their corresponding institutions do to physical, geographical, medical, or other sciences.

SECTION G.—ENGINEERING.

PRESIDENT OF THE SECTION.—PROFESSOR GISBERT KAPP, M.Sc., D.Eng.

THURSDAY, SEPTEMBER 11.

The President delivered the following Address :—

ENGINEERING, the subject with which Section G is concerned, covers so wide a field that it has been found convenient to introduce a rough sub-division into the three branches of civil, mechanical, and electrical engineering. By applying any such term to a particular piece of engineering work we do not necessarily exclude the others; we merely characterise a predominant feature. There is often a considerable amount of overlapping between the three branches, and that is especially the case with mechanical and electrical engineering. Sometimes the boundary-line even becomes indistinct, and then it is difficult to say which branch of our science is the predominant feature. Is the equipment of a works with electric-power mechanical or electrical engineering? It is both, but not necessarily to the same degree. The mere replacement of a steam engine by an electric motor to drive the main shafting of a works can hardly be called a piece of electrical engineering; but if special electric appliances are introduced to perform duties which cannot be done, or not done as well, by purely mechanical machinery, then we have electrical engineering in the true sense of the term.

Electricity has invaded almost every branch of our industrial activity, sometimes as a rival to older methods, but often also as a helpmate, stimulating progress all round. Electricity is a 'great source of power in nature,' and the 'art of directing it for the use and convenience of man' belongs to our generation. Yet, like all new things, it has had to fight its way in the face of strenuous opposition —generally an absolutely honest opposition, not in any way traceable to self-interest, but simply to inability to see things in the right perspective. Let me illustrate my meaning by an example. Shortly after Charles Brown had established the first electric-power transmission between Kriegstetten and Solothurn I happened to visit a well-known mechanical engineer in Zurich, who had in his time been professionally (not financially) interested in so-called teledynamic transmission of power by wire-rope, first introduced into Alsatia by the celebrated Professor Hirn, of thermodynamic fame, about the middle of last century, and then also imported into Switzerland. To my old friend these transmission systems appeared to be the acme of perfection; and on my pointing out that the range was necessarily very limited, he replied that transmission to longer distances would be useless, since there would be no market for the power. My friend was not able to look at the subject in the right perspective; he failed completely in appreciating the fundamental conditions of the problem, and although it is easy for us now, fortified as we are by experience, to appreciate electric transmission of power correctly and feel contempt for the old gentleman's narrow-mindedness, yet we should be careful not to fall into the same error about electrical developments which are new to us, as the transmission of power was new to my Swiss friend. It is not so very long ago that mechanical engineers

thought there was no advantage in electrifying textile mills; and I do not feel quite certain whether a good many and very capable engineers are not still of the same opinion. A commission has been investigating this subject, and its first report was by no means encouraging to the electrical engineer. Yet at the very time when that report was issued hundreds of motors were being installed in Continental mills. The spinners there had found out that by using a motor with very delicate speed regulation they could speed up their frames and increase the output considerably. In the long run a good thing must win through, and the electrification of English textile mills is no exception to this economic law; but in some cases it would almost seem that the way is made longer by the narrowness of the mental horizon of opposing experts. This process of gradually overcoming the opposing expert had to be gone through in all applications of electricity, but, the opposition being generally honest, once it is overcome, the very men who opposed become strong friends. There is no question now that electricity can do some things better than could be done formerly. The separation of magnetic from nonmagnetic material; the lifting of hot pigs, ingots, plates, and scrap by electromagnets; the production of high-grade steel in the electric furnace; the sinking of shafts by electrically driven pumps; in mines the use underground of electromotors instead of steam engines, in shipyards the use of magnetically-fixed and electrically-driven tools; the electric driving of rolling mills, and the use of electric traction on tube and other underground railways are familiar examples of the application of electricity in which unanimity as to its advantages has been reached between the electrical engineer and what, without any intention of being disrespectful, we may call the old school of mechanical engineers. There are, however, other applications of electricity where the old and new school of engineers have either not at all, or only partially, reached unanimity of opinion, and it is with one of these applications—namely, the electrification of railways—that I propose to deal in this Address. As regards urban and suburban lines, not only the possibility of electric traction, but its immense superiority over steam traction, is fairly generally admitted. Where we get on debatable ground is when we begin to discuss main-line traffic. Here the process of overcoming opposition, of which I spoke a moment ago in connection with other applications of electricity now generally approved, has only just begun. Will it lead to the same result, or will the electrician have to confess himself beaten by the steam locomotive? The answer each one of us would give to this question must necessarily be biased by our early training. Most engineers love their profession, and are enthusiasts; being enthusiasts, they are necessarily biased. This applies as well to the electrical engineer as to the mechanical engineer—perhaps to the electrical engineer most. In many cases he is so biased that he will not admit any virtue in any other but his own pet scheme of electric traction. A modern steam locomotive is a beautiful and efficient engine, and one can well understand its designer looking at it with the pride of a father whose son has turned out a good man. One can also understand that this engineer will not readily admit the superiority of an electric locomotive. The mental horizon of each of us must necessarily be narrowed by previous training and professional enthusiasm; let us, then, try to forget for a moment that we are engineers, and let us put out of our minds all questions of mechanical or electrical detail, focussing our thoughts merely on what we see going on all around us as regards electrification of railways. We see year by year more lines being electrified. Some are failures; but the very fact that in spite of these failures the process of electrification is going on, shows that the failures are remediable. In some cases it is easy to understand why a line should be electrified. If fuel is dear, if the trains must be heavy and frequent, if there are steep grades and long tunnels, then obviously steam is at a disadvantage and electricity can beat it easily. But the electrification is not limited to cases where there are such obvious advantages. We see a military State like Prussia electrifying a fairly long line where the traffic is not extremely heavy, where there are very gentle grades, and only few and short tunnels. Moreover, one of the stock arguments against electrification is that in case of war the whole system may be broken down by the enemy cutting the wires; yet this consideration, if it has any weight—a matter on which I cannot pronounce an opinion—does not deter a military State from at least experimenting with electric traction

on a large scale. We see suburban lines growing longer and longer, until they might almost be classed as short main lines, and we see the Swiss Government buying up water-powers with the object of utilising these powers in the electrification of its most important main lines. We see in America the electrification of large systems taking place, not only for passenger service, but also for the goods service, comprising trains of 2,000 and more tons weight, and of goods yards, to the complete exclusion of steam. One need not be an engineer to appreciate the significance of such a general development. No Government department, and certainly no board of railway directors, will spend money merely for the sake of an interesting scientific experiment, and, although it is conceivable that in an isolated case such an experiment may be undertaken under a miscalculation as to its possible success, it is not conceivable that such a miscalculation should be the general rule. When we see that in all countries a vast amount of labour is devoted to, and capital is spent on, the electrification of main lines, we cannot but come to the conclusion that this new application of electricity is bound to progress, and that the persons who tell you that electric traction is all right for tramways and urban railways, but will never be able to compete against steam traction on main lines, are very much in the position of my old Swiss friend, whose conception of power transmission was entirely limited to the use of ropes and pulleys.

It is just thirty years since the first electric railway was opened for public use. That was a small line in Ireland, known as the Portrush-Bushmills Railway. In those days only the continuous-current motor was available, and that only at a very moderate pressure and power. These restrictions were from the first felt to be a serious drawback, and inventors tried to overcome them in various ways. Of these, two may be here noted, in passing. Ward Leonard in 1891 made the suggestion of carrying on the train a converting station. He argued, quite correctly, that for the transmission of power to long distances the alternating current was eminently suitable, and that, consequently, the power should be sent to the train in the shape of high-pressure alternating current. On the other hand, such a current was, in those days, quite unsuitable for motors; hence the necessity of its conversion into continuous current, with which the then available motors could alone deal. Ward Leonard suggested to put on the first vehicle of the train a synchronous motor, which drives an exciter and continuous-current generator. The current obtained from this generator was to be used to drive the train-motors, which might be distributed in a number of motor coaches. The regulation of speed and tractive force was to be effected entirely by suitable adjustment of excitation, and therefore without rheostatic loss. It will be admitted that this proposal has some attractive features. It is essentially a long-distance system, and at the same time it offers the possibility of great and uniform acceleration, a matter of great importance in urban traffic, so that it is equally suitable for both kinds of service. Moreover, the current can be taken with unity-power factor. Unfortunately the extra weight which has to be carried in the shape of converting machinery is a serious drawback; and for this reason the Ward Leonard system (excellent as it has proved in other applications of electric power) has in the domain of traction never got beyond the experimental stage.

The experiment has been made on a fairly large scale, but with this difference, that the traction-motors were placed not into motor coaches, but on the first vehicle itself, which thus became an electromotive; also, in order to save the weight and cost of starting and synchronising gear, the asynchronous type of single-phase motor was adopted, thus sacrificing the advantage of unity-power factor. The electromotive developed at the hour-rating 200 horse-power, and weighed forty-six tons. This is not a very brilliant achievement, and it was beaten by a sister engine of the same power, but using alternating-current motors. This electromotive weighed only forty tons.

It is probable that a better weight efficiency could be obtained nowadays with this system if carried out on a larger scale, and if the motor-generator were replaced by a converter, in which case the step-down transformer would have tappings on its secondary side for starting and regulation. It is, however, doubtful whether even then it could compete with electromotives using the alternating current in the motors directly. Motors of this type have recently

been so much improved that the margin of weight that could be saved by the use of continuous-current motors is probably less than the excess weight of the converting machine.

The other attempt to combine high trolley-voltage with low motor-voltage has shared the same fate. This consisted in the application of the three-wire principle of continuous current supply to electric traction. It is in successful operation at a moderate voltage on a London tube railway, but as far as main-line working is concerned it has not got beyond an application on two small lines in Bohemia. The principle adopted is to make the trolley wire of the up-line the positive and that of the down-line the negative side of the system, whilst the rails take the place of the zero wire. Each electromotive is fitted with four motors, of which at least two are in series, taking 1,500 volts. Thus, whilst the voltage of one motor is kept within the customary limit of 750 volts, the pressure of the whole system is 3,000 volts. The objection to this arrangement is that its fundamental supposition of a fairly close balance between the two halves of the three-wire system must in actual railway working be rather the exception than the rule, and that the obvious remedy of combining both halves of the system in one and the same train would involve the use of two overhead trolley wires, and thus introduce the very feature which the advocates of the continuous-current system find so objectionable in three-phase traction. Moreover, the recent improvements made in continuous-current motors has reduced the importance of the three-wire principle. Continental makers are prepared to build motors for 1,200 volts, and one English maker is actually building motors for 1,750 volts, so that with two motors in series a trolley-pressure of 2,400 and 3,500 volts respectively can be used.

The present tendency in electric traction is in the direction of simplicity, in the sense that mixing up of different types of current and dependence of one train on another is avoided. Only three types of current are used—namely, continuous, three-phase, and single-phase. The two first-named are used direct; the last through the intervention of a transformer. In a large measure the different systems have already become standardised. As regards the C.C. system, up to 750 volts the process of standardisation has been completed long ago. It is almost generally adopted for urban and suburban lines of moderate length, unless there are local difficulties as regards the third rail, or it is desired to work the suburban and the main-line service on the same system. The three-phase system has also been fairly well standardised, but the single-phase system is still in a process of development—a development which, however, takes place on a fairly large scale. In France the Compagnie du Midi is electrifying on the single-phase system nearly 400 miles of track; the German Government have already electrified the Dessau-Bitterfeld of the Leipzig-Magdeburg line, and are electrifying the line Lauban-Koenigszelt in Silesia, to say nothing of some smaller private lines in the South of Germany, which have been in operation for some years. In Switzerland the Berne-Loetschberg-Simplon Railway, already in operation, and the Rhætian Alp Railway, nearing completion, also employ single-phase electromotives. Both in France and Germany the type of electromotive to be finally adopted has not yet been settled, but half-a-dozen different types, supplied by as many different makers, are being tried, and it is in this respect that one may look on single-phase traction as still in the process of development. As regards the Loetschberg the period of trial is over. Three years ago the railway company ordered a 2,000 horse-power electromotive, and have had it at work ever since with such satisfactory results that they have decided to adopt this type definitely, and have ordered thirteen more engines, but of the slightly larger power of 2,500 horse-power on the 1½-hour rating. Of these I shall have to say something more presently; but before entering into the details of single-phase traction it is expedient to glance briefly at the present position of the rival system of three-phase traction.

The first application of this method of working dates back to the end of last century, and took place on a small Swiss line; then followed the well-known Valtellin line, and, later still, when the Italian Government took over the railways, the Government engineers decided to extend the application of three-phase traction to some other lines—a decision which practical experience has shown to have been perfectly justified. The total power represented by three-phase electromotives either at work or on order in Italy to-day exceeds 200,000 horse-

power (95,000 horse-power in service, and 120,000 horse-power building). Ten years ago the three-phase system was the only possible one for main-line working, but later on there came on the scene the single-phase, and, later still, the high-pressure continuous-current systems, and I need hardly mention that between the advocates of the three systems there has been waged a fierce battle, each claiming that his is the best and the others very inferior. I am afraid that battle is still raging; but it is a futile war, for there is no such thing as a best system generally. One system is the best for one set of conditions and another for another set. Thus the German railway engineers found that the single-phase system would serve them best, and they adopted it. There is in this matter no question of personal feeling or national prejudice. I have no intention to enter the lists as an advocate for any one of the three possible systems for main-line traction; each has its special features and special merits, and all I can do is to place before you some of these. As the three-phase system is the oldest, it will be convenient to take it first.

It is curious to note that the three most obvious objections which have been raised against three-phase electromotives by theorists have been found to have but little weight in practical work. These objections were: the complication of a double overhead wire, the danger that the motors would not share the load fairly, and the inability to run without rheostatic waste at intermediate speeds, or to run at a higher than synchronous speed to make up for lost time.

That an overhead wire is inconvenient must be readily admitted. but the inconvenience applies to all methods of main-line working, for the so-called third rail is not applicable to high pressure, and even if it were, the consideration of the safety of the platelayer would preclude its use. The question then is: are two wires twice as objectionable as one? Possibly, but the most objectionable feature is not the wire itself, but the posts or gantries on which it is carried, and the number of posts is the same, whether we use three-phase, single-phase, or continuous current. There is a little more complication at the cross-over points and at the switches; but this is not a serious matter, if one may judge from the perfectly smooth working of so extended a yard as that at Busalla, where there are five miles of track, connected by thirty-seven switches and crossings. The other objection—as to the motors not sharing the load equally—is theoretically sound. The torque developed by the motor is proportional to the slip, and in order that the two motors on an electromotive shall share the load equally their slips, and consequently also their speeds, must be the same. Now, it is conceivable that, owing to a slight difference in the size of the drivers, that motor which is geared to the larger drivers will, by reason of its lower speed and consequently greater slip, take more than its fair share of the load. In practice this difficulty does, however, not arise. With reasonably good workmanship there should be no sensible difference in the size of the wheels; but even if we admit the possibility of there being a difference of a half per cent. in the diameter of the wheels, this would, with the usual slip of three per cent., only mean that the motor geared to the larger wheels develops eight per cent. more, and the other eight per cent. less, than its normal power. The larger wheels will develop sixteen per cent. more tractive effort than the smaller wheels, and having thus a greater wear, the difference originally existing will diminish in service. For the same reason, any tendency to wear unequally, say, in consequence of unequal material, is counteracted by the slip-adjustment of the motors. This point has been tested practically by the makers of the Simplon three-phase electromotives. It was found that if originally a slight difference in diameter of the drivers had been permitted to exist, after a short time this had vanished. That is as regards the condition on one electromotive; but if we come to the case of a train being hauled by two engines, then a sensible difference in the size of their wheels may exist. In this case it is necessary to artificially adjust the slip so as to make each motor take half the load. This problem has been solved by Mr. v. Kando in the electromotives which he designed for the Italian State railways. In these engines only liquid resistances are used in the rotor circuit for starting and speed regulation. The liquid is raised or lowered in the rheostat chambers so as to cover more or less of the contact plates, and the level of the liquid is controlled by a solenoid under the influence of the working current. The working current, and therefore also the tractive effort exerted by each motor, is thereby auto-

matically kept constant, notwithstanding any difference that may exist in the size of the drivers on the two electromotives. Incidentally, it may be mentioned that this method of liquid rheostat control has also the advantage of a perfectly constant acceleration during the starting period—a point which makes for comfort of travel in a three-phase train.

The third objection advanced by theorists against three-phase traction is against the waste of energy consequent on rheostatic speed control and the inability to run at more than synchronous speed so as to make up for lost time. The obvious remedy for the last-named difficulty is to fix the time-table so that the synchronous speed should be high enough for making up lost time and to employ motors which can run economically at less than synchronous speed. As a matter of practical experience three-phase trains are not more unpunctual than any other kind, steam not excluded. A train pulled by a series motor (C.C. or A.C.) runs slower on an up-grade or if abnormally heavy; this is one of the characteristics of the series motor, and it is valuable, because it limits the excess load thrown on to the source of power; but it is clearly not a condition making for good time-keeping. With a series motor time lost cannot be recovered on an up-grade, whilst with a three-phase motor the speed on an up-grade may be kept practically the same as on the level or on down-grades, so that the process of gaining time is not restricted to the easy parts of the line.

The problem of speed control without rheostatic waste has been solved in various ways. One of the simplest and generally adopted solutions is that of cascade and single working. If the two motors are put into cascade connection the speed is halved. The cascade is used in starting and on heavy grades (unless time has to be made up), and on the easy grades or on down-grades the motors work singly—that is to say, in simple parallel connections. Intermediate speeds may be obtained by some pole-changing device. Ordinarily, such devices have to be applied to stator and rotor, but in some of the Simplon electromotives only the stator is arranged for pole-changing, the rotor being a squirrel cage. In this arrangement the advantage of cascade-working has to be given up, but the system has the merit of great simplicity. The number of poles may be changed from twelve at starting to eight, six, and four at top speed. Thus, four different speeds, all without rheostatic waste, are possible. The single bars in the squirrel-cage rotor are connected at their ends by resistance-connectors made of an alloy having a high temperature co-efficient. At starting the rotor current is large and heats up these strips, thus automatically providing what is technically termed a starting-resistance. When the motor is running the current is less, and by reason of the fanning action of the connecting-strips these get cooled so as to bring their resistance down to a permissible amount. Thus the efficiency of the motor when running under load is only a few per cent. less than that of a motor with a wound rotor. A valuable feature of the three-phase system is the automatic recuperation of current whenever the speed exceeds synchronous speed by a few per cent.; and connected with this property is the further advantage that it is impossible for a train to race on a down-grade. Obviously recuperation can only take place if power is given to the motor. This is provided partly by the electromotive itself and partly by the train pushing it on a down-grade. This means that the train is braked in front only, and railway engineers have raised the objections that such a method is contrary to the accepted rules for safe working, which requires that even on a down-grade all the couplings should remain in tension, which means that each coach must be independently braked. Here we have again a case where the theorists' objections have been proved to be without foundation in actual practice. It is no doubt objectionable to brake a train in front only, if the braking action is jerky; but with the automatically controlled liquid rheostat the braking comes in quite gradually, and is throughout so even that it has been found possible to permit a higher down-grade speed with recuperation than with ordinary braking. On the Italian State Railways the regulation permits on heavy down-grades a speed of thirty kilometres per hour for steam trains, but the electric goods trains are permitted to run at forty-five kilometres per hour. This concession is not extended to passenger trains. Nevertheless tht economic effect is considerable. Recuperation saves 17 per cent. on the coal bill, and this amount is sufficient to provide for interest and sinking fund on the electrical plant at the generating station.

One advantage of three-phase traction over steam traction is the lessened

weight of the locomotive in comparison with its tractive force and power. As an example, we may take the Giovi line in Italy, where steam trains, consisting of 310 tons of rolling-stock and 202 tons of locomotive (one in front and the other at the back), have been replaced by three-phase trains, consisting of 380 tons of rolling-stock and two electromotives, each weighing 60 tons (also placed front and rear). Thus there has been a saving in total weight of 12 tons, and at the same time an increase in useful weight hauled of 70 tons. The average grade of this line, over which passes the whole traffic between the Port of Genoa and the Plain of Lombardy, is 27 per mille, and the maximum is 35 per mille. This traffic is now worked with forty electromotives, each of 60 tons weight. These engines have five driving-wheels connected to two eight-pole motors by gearwheels and rods. The pressure on each driving-axle is 12 tons. Each electromotive develops 2,000 horse-power at the hour-rating; thus 1 horse-power is obtained for each 30 kilogramme weight of engine.

The number of patented designs for single-phase traction motors is very large; but, notwithstanding considerable difference in matters of detail, all motors which have been successfully applied in practice may be ranged under three great groups—namely, the so-called repulsion type, the repulsion type with additional excitation of the rotor, and the straightforward series motor. The present tendency is rather in favour of the series motor, and the practical results obtained with it are certainly very promising. The latest design made by Dr. Behn-Eschenburg shows a remarkable weight efficiency. His 2,500 horse-power electromotives (the power being at a one and a half hour-rating) weigh only 108 tons, so that at this rating 1 horse-power is obtained with a total weight of 43 kilogrammes. This compares favourably with the high-pressure C.C. system, where 50 to 70 kilogrammes per horse-power may be taken as normal values.

The so-called 'repulsion motor' invented by Professor Elihu Thomson has been applied to railway work in the slightly modified form due to Mr. Deri, where, instead of there being only two brushes per pair of poles, double the number is provided, and the adjustment for speed and torque is made more accurate, whilst at the same time the commutation, being split up into two steps, becomes easier. In the matter of simplicity, an electromotive fitted with Deri motors cannot be surpassed by any other arrangement. There are no rheostats, contactors, control switches, or other gear; all the regulation is effected by mechanical transmission of the movement of a hand wheel placed in the driver's cab to the brushes of the motors. At one time it was hoped that this system would win its way to a general application; but, unfortunately, the rotor must run somewhere near synchronous speed, and becomes therefore rather heavy with the low frequencies alone possible in traction. Moreover, as the power factor obtainable is only about 0·80, that is, considerably below the value obtainable with other motors, there does not seem to be any great future for this system for heavy work, although its great simplicity may still turn the balance in its favour on lines with a light traffic. For heavy lines the choice at present lies between the induction-motor with direct rotor excitation and the straightforward conduction-motor, where rotor and stator are traversed in series by the same current. The former type of motor—also called the Latour-Winter-Eichberg motor—depends for its working current in the rotor on electro-magnetic induction, which produces the working current in the rotor much in the same way as the current in the secondary circuit of a transformer is produced by induction. Since the motor has in part the character of a transformer its weight would, as is the case with any transformer, be unduly augmented by too great a reduction in the frequency. Experience has shown that a frequency of twenty-five periods per second is high enough to render the transformer action effective, and at the same time not so high as to introduce serious difficulties as regards e.m.f. of self-induction and commutation. This frequency has been adopted in most cases where electrification of main lines has been carried out by motors of this class. One valuable feature of this motor is that at a speed slightly exceeding synchronism the power-factor may be brought up to unity. At this speed the commutation takes place under conditions which may be described as theoretically perfect. A fair number of Continental lines have been electrified by using these motors, and they have also been adopted, with very satisfactory results, in the electrification of the London, Brighton and South Coast lines between Victoria and London Bridge and to some distance

south of London. On this line no locomotives are used, but only motor coaches. It is therefore not possible to make a direct comparison as to weight efficiency with a locomotive. The latter has only to carry the propelling machinery, whilst the former has to provide accommodation for passengers as well. The 600 horse-power motor coaches on the Brighton line weigh 50 tons, or at the rate of 83 kilogrammes per horse-power. A 1,000 horse-power C.C. electromotive taking current at 1,200 volts weighs 74 tons.[1] By making a suitable reduction for the extra weight of the passenger accommodation in the A.C. coach, its weight per horse-power comes out at something like 60 kilogrammes, against 62 kilogrammes in the C.C. engine.

Series motors are employed on the electrified lines of the Midland Company between Heysham, Morecambe, and Lancaster. Also in this case motor coaches, and not electromotives, are used. At the hour-rating a motor coach develops 420 horse-power, and as its total weight is about 35 tons, we have here the same weight-efficiency as on the Brighton lines—namely, 83 kilogrammes per horse-power for the whole coach.

Of high-pressure continuous-current lines there are many examples, both in Europe and America. The term high-pressure does, of course, not imply the same order of magnitude as in single-phase A.C. lines. There high-pressure may mean anything up to 15,000 volts, the pressure which is likely to become a standard in future electrifications; but in C.C. work one must class anything over 1,000 volts or 1,500 volts as high-pressure. The general rule is to employ motor coaches, and not electromotives; but there is a private line belonging to a steel-works in Lorraine, where two electromotives, each of 600 horse-power (four C.C. motors of 150 horse-power) are working the mineral trains under a pressure of 2,000 volts. The Southern Pacific Railway also employs C.C. electromotives of 1,000 horse-power each. Each engine weighs 74 tons, and hauls a train of 270 tons on grades of 40 per mille. This is a remarkable performance, rendered possible by the fact that with the even torque exerted by the electric motor a much larger co-efficient of friction than is possible in steam traction may safely be permitted. Electrical engineers generally base their calculation of the possible tractive effort on a co-efficient of 0·17, without sand, and as high as 0·25, or even 0·28 if sand is used. The voltage in the case of the Southern Pacific engines is only 1,200 volts, taken by two motors in series, and there is provision made to change over from the overhead wire to third rail, with 600 volts, when the motors are all in parallel. On European C.C. lines the voltage is higher—generally 2,000 volts, as on the Chur-Arosa and some other Swiss lines—and the tendency is still in the direction of higher pressures. Continental makers are now prepared to go as far as 1,200 volts per motor, so that with the usual system of series-parallel control a line-pressure of 2,400 volts becomes possible. The greatest step in advance in this direction has, however, been made in England, where Messrs. Dick Kerr, Ltd., have adopted a line-pressure of 3,500 volts as their standard, involving the use of motors constructed for 1,750 volts. After having experimented with this high-pressure system for two years, they have undertaken the electrification of a short section of the Lancashire and Yorkshire Railway with continuous current at 3,500 volts. I am indebted to the firm for the following particulars: The current is collected by pantograph from an overhead wire with catenary suspension. The train consists of a motor coach and two trailers. The motor coach is equipped with four 300 horse-power motors, and weighs 62 tons; the trailers weigh each 26 tons. From these figures it will be seen that the weight of the motor coach per horse-power is only 52 kilogrammes, and thus considerably below what the weight of an equivalent single-phase motor coach would be. It is especially the saving in weight and the avoidance of any telephonic disturbances which renders the C.C. system so attractive that, in spite of a natural reluctance against the use of high-pressure on a commutator, designers are giving increased attention to the use of continuous current for electric traction. The difficulties which some engineers anticipate with commutator and brushes seem, however, rather imaginary than real, if we may judge from the experience with the 3,500-volt motor coach. The makers inform me that they estimate the mileage for a set of carbon brushes at 50,000 miles.

[1] See Gratzemueller's paper read at the Paris meeting of the I.E.E. and S. Intern. des Electr. (Paris, May 1913).

The motors drive the car-axles by single reduction gear, and are controlled by contactors operated from a master controller. The current for operating the contactors, driving the air-pump motor, and for the general service of lighting and heating is obtained from a small motor-generator, fed on the primary side at 3,500 volts, and delivering C.C. at 210 volts. All motors have commutating poles—a practice which has become universal in C.C. traction work.

From the figures quoted above it will be seen that where motor coaches are employed the C.C. system has an advantage in point of weight over the single-phase A.C. system. But main-line traction, including goods trains, is not going to be done by motor coaches, and if we come to large electromotives of some 2,000 to 3,000 horse-power then this advantage is likely to vanish. No high-pressure C.C. electromotive has as yet been built for so large a power, and it is therefore not possible to make a direct comparison; but, if we may judge from the largest engines yet built for moderate-pressure C.C., there is little probability that the C.C. system for high-pressure can beat the single-phase system, and none whatever that it can beat the three-phase system.

In the early days of single-phase traction some trouble has been experienced in the matter of telephonic disturbance. A systematic investigation carried on for over a year on the Seebach-Wettingen line, chiefly by means of the oscillograph, showed that this trouble was due, not as had originally been suspected, to the commutator, but to the employment of open slots in the rotor, and the trouble nearly ceased when new rotors with semi-closed and spiralled slots were used. To further improve the telephonic service the usual remedy of metallic return and drilling the telephone lines was employed. Although by these means it is possible to render telephonic speech over a line alongside a single-phase railway nearly, and perhaps quite, as clear as it is along a C.C. railway, there still remains the danger that the telephone lines may, by electrostatic induction, acquire a very high potential. The remedy against this danger, first applied on some Swedish experimental lines, is to short-circuit the two wires of each circuit by a choking coil of very high inductance, the centre of which is earthed. The static charge is thus carried off to earth, whilst the telephonic currents are only inappreciably weakened.

One of the advantages possessed by the alternating over the continuous current is the simplicity of regulation. There are no contactors and no rheostats used, the power and speed of the motors being adjusted by the use of tappings on the secondary side of the transformers. As transformers are necessary in any case in order to work with a high voltage on the trolley, the introduction of tappings does not materially increase the weight, whilst at the same time it affects a great reduction in the primary starting current. The only difficulty that still remains is that of sparkless commutation, and inventors have evolved many, and sometimes very complicated, arrangements for overcoming it. As so often happens with engineering problems, the most simple solution is, after all, found to be the best in practice; and of all the ingenious inventions patented during the last ten years very little use is made by the designer of traction motors. Broadly speaking, only two methods are in use; the one is the method first made known by Messrs. Winter & Eichberg, where the working field is produced by direct excitation of the rotor and the transformer e.m.f. in the coils short-circuited by the main brushes is balanced by an e m f. of rotation due to a transverse field; and the other method applicable to the straightforward series motor, where a non-inductive shunt is connected to the terminals of the compensating or commutating winding. The effect of a non-inductive shunt is to make the armature field slightly leading over the field produced by the compensating winding. The resultant of these two fields is in position coincident with the brush axis, but has in point of time a phase difference of a quarter period over the working current, thus balancing the e.m.f. of self-induction, which lags by a quarter period. Obviously this balancing effect can only take place when the motor is running, since it depends on the balance between an e.m.f. of self-induction which is independent of speed and an e.m.f. of rotation which is proportional to speed. At starting, when there is no speed, there is no compensation. Thus there would appear to be a new difficulty in the way of the use of single-phase current; but also this has been overcome in quite a simple manner. Experience has shown that a potential difference of seven volts between heel and toe of brush,

and a current density of 15 A. per sq. cm., is permissible. If, then, we use narrow brushes, covering at any time not more than three segments, use coils of only one turn to each segment, and work at a reasonably low frequency, and not too high a total flux, it is possible to keep the transformer voltage and current density well within the above limits. This is not a severe limitation, for it enables the designer to use a flux out of one pole of 2·4 megalines if the frequency is 25, and 3·6 megalines if it is 15. The number of poles has then to be selected in accordance with the power desired. Obviously the lower periodicity is to be preferred, because the motor may be built with a lesser number of poles, and will then occupy less room—a matter of considerable importance, considering the limited space which is available in an electromotive. The frequency of 15 has also some other advantages over that of 25. The e.m.f. of self-induction is proportionately less, and, in consequence, the power-factor is about five per cent. better. The skin effect in the rails is much reduced, and also disturbances on neighbouring circuits which may be due to inductive or capacity effects. On the other hand, the generators become a little more expensive and the transformers on the electromotives a little heavier. But, notwithstanding these drawbacks, the balance of advantage is with the lower frequency, and that is the reason why the Commission of Experts called together in 1904 by the Swiss Government to establish standards for the electrification of the Swiss railways has decided that 15 shall be the standard frequency, with a tolerance down to 14, and up to $16\frac{2}{3}$. Since then other States have fallen into line, so that 15 is now the standard frequency nearly all over the continent of Europe. The standard pressure is likely to be 15,000 volts. For three phase traction the standard pressure is 3,000 to 3,300 volts.

The subject of electric main-line traction is so vast that in the limited time at my disposal I have only been able to mention a few of the important features of this interesting problem. A detailed account of all that has been done in electrification would take far more time than we can spare; but, by way of example, I give below two tables referring to the Italian State Railways. I am indebted for the information to Mr. v. Kando, who may justly be described as the father of three-phase traction.

Italian State Railways Electrified on the Three-phase System.

	In Service			In Construction		
Location of Line	Lecco Colico Sondrio Chiavenna	Campasso Pontedecimo Busalla	Bussoleno Bardonecchia Modone	Savona S. Giuseppe Ceva	Lecco Monza	Genova Sampierdarena Ronco
Length, in kilomètres	107	19	58	45	38	28
Heaviest Grade per mille	22	35	30	25	12	17
Number of Transforming Stations	10	4	7	4	4	2
Transmission Voltage	20,000	13,000	59,000	62,000	25,000	57,000
Trolley Voltage	3,000	3,000	3,300	3,300	3,300	3,000
Frequency (cycles per second)	15	15	$16\frac{2}{3}$	$16\frac{2}{3}$	$16\frac{2}{3}$	15
Source of Power	Water	Steam	Water	Water (Steam Reserve)	Water (Steam Reserve)	Water (Steam Reserve)
Number of Electromotives	14	20	15	61 for the three lines		
Number of Motor Coaches	10	—	—	—	—	—
Weight of Trains, minimum	150	190	—	not given		
Weight of Trains, maximum	370	380	220			

Three-phase Electromotives on the Italian State Railways.

Type	034	036	038	050	030
Maker	Ganz	Ganz	Ganz	Westinghouse	Westinghouse
Number in Service	2	3	4	40	—
Number Building	—	—	—	45	16
Total Weight, tons	45	62	62	60	66
Weight on Drivers	45	43·5	43·5	60	48
Number of Driving Axles	4	3	3	5	3
Total Number of Axles	4	5	5	5	5
Weight on Drivers, tons	11·3	14·5	14·5	12	16
Diam of Drivers, m.m.	1,396	1,600	1,600	1,070	1,630
Frequency (cycles per second)	15	15	15	15	$16\frac{2}{3}$
Method of transmitting torque of motor to driving axles	Quill and flexible Coupling	Cranks and Connecting Rods			
Speed, in kilomètres per hour	30	32—64	22—45—63	22·5—45	37·5—50—75—100
Method of Speed Regulation	—	Cascade	Cascade	Cascade	Cascade and pole-changing

The most recent example of single-phase electrification is that of the Loetschberg line establishing direct communication between Berne and the Simplon line. I am indebted to Dr. Behn-Eschenburg, the designer of the electromotives, for the following information. The power at the one-and-a-half-hour rating is 2,500 horse-power, and the total weight of the engine is 108 tons, of which 85 tons is taken by the five driving axles. At the normal speed of 50 kilomètres per hour the tractive effort is 10 tons. This can be increased at starting to 18 tons. On the heaviest grade (27 per mille) the tractive effort is 13·5 tons, which suffices for a train of 310 tons. The maximum speed is 75 kilomètres per hour. There are two 1,250 horse-power motors on each engine. Each has its own transformer and controller, the principle of duplication being carried out in all the details, so that in the event of a defect to any one part the other remains serviceable. The potential difference between tappings is 45 volts, and the last step gives with 15,000 volts on the trolley 520 volts. This is in excess of what is required by the motor, and thus provides for the event that the trolley-voltage should for some reason fall below the standard pressure. The normal voltage of the motors is 420, and the full-load current 2,700 A. At starting on the level the line-current is about one-third of the full load-current, and the power ten per cent. of the full power. When starting on an up-grade of 27 per mille with a train of 310 tons the current taken from the trolley is forty per cent. of the normal full-power value, and the acceleration ·05 mètres per second per second. The current is taken from the overhead trolley by two pantographs, the pressure being 15,000 volts, and the frequency 15. The controller drums are each worked by an electromotor and rocking pawls under the electric control of a master controller, so that the driver is relieved of any physical exertion in attending to the regulation of the motors. These have 16 poles, a compensating winding to increase the power-factor, and commutating poles shunted by a non-inductive resistance to insure sparkless collection. The power-factor is about 0.95 over a wide range of load. The motor is geared by double helical wheels (ratio 1 : 2·23) to a blind axle, from which the turning moment is transmitted to the drivers by cranks and connecting-rods. The weights are as follows: Motor, 11·8 tons; gear, 2 tons; transformer, 7·5 tons; and controller, 1 ton; total, 22·3 tons; or at the rate of 17·8 kilogrammes per horse-power on the one-and-a-half-hour rating. The total weight of the electromotive is at the rate of 43 kilogrammes at the same rating. This is a remarkably high weight-efficiency,

which has up to the present not been reached by any continuous-current electromotive, and has only been surpassed by the three-phase 2,000 horse-power electromotives (taken at the one-hour rating) of the Italian State Railways, which works out at 30 kilogrammes per horse-power.

In conclusion, let us briefly glance at what is being done in the electrification of the Gothard line, that main link of commerce between Germany and Italy. I am indebted for the following notes on the subject to Mr. Huber-Stocker, the scientific adviser to the Swiss Government in the matter of Railway Electrification: The part to be electrified first is that between Erstfeld and Bellinzona, a total length of 110 kilomètres, of which about 29 per cent. is in tunnel. This part also contains the longest and heaviest grades, so that the limitations of steam as compared with electric traction are here most prominent and a relief most urgent. On this section the average daily train movement, taking both directions together, was, in 1911, not less than 1,680,000 kilomètre-tons, and the maximum on any day 2,282,000 kilomètre-tons. It is estimated that in 1918 the average train movement will have increased by 35 per cent. over 1911, and in 1928 by a further 30 per cent. In the 45 kilomètres on the north side of the tunnel the train climbs 569 mètres, and in the 65 kilomètres on the south it descends to Bellinzona 900 mètres, with a steepest grade of 27 per mille. The section Erstfeld-Airolo is to be opened for electric traction in four years from now, and the southern section one year later. The present arrangements are made with the intention of extending the electric service on the north to Lucerne (60 kilomètres), and on the south to Chiasso (55 kilomètres) at some future date not yet fixed. There will be two large power-stations, one at Amsteg, where at first 32,000 horse-power will be available on the turbine shafts, and 56,000 to 60,000 when the station is completed; and the other at Piotta, where at first 40,000, and finally 50,000 horse-power will be available. The head of water in the northern power-house is 267 mètres down to the Reuss, and an accumulation of a million cubic mètres is provided for to compensate for diurnal variations. In the southern power-house the head of water is 900 mètres, and there the Ritom Lake offers a natural reservoir, with 19 million cubic mètres, to compensate for annual variation in the water-supply. The power-current will be sent along the line by two independent cables, each capable of carrying the full power at twice 30,000 volts, with earthed neutral. The current will be transformed down to 7,500 volts at first, and 15,000 volts later on, if the experience gained with the lower pressure should warrant the increase to double pressure. This will not involve any additional plant, since the secondary winding of transformers both along the line and on the locomotives can from the first be arranged with this alteration in view. It is also contemplated to establish sub-stations in Biasca, Goeschenen, Lavorgo, and Bellinzona. The trolley wires will be suspended from gantries, each wire independently insulated. The section varies according to the gradient from 100 to 160 square millimètres. The feeders are separate for the up and down line, and are 100 square millimètres in section. At all railway stations there are change-over switches for trolley wire and feeders. In the tunnels the wires are carried by brackets fastened to the crown of the tunnel. The rails will be bonded, and, in addition, there will be a bare return conductor either laid in the ground or placed between the trolley wires. A variation in the supply of voltage of from plus 10 to minus 15 per cent. is allowed for. There will be no motor coaches used, only electromotives. It is intended to haul express trains weighing 420 tons with a speed of 50 kilomètres per hour on grades of 26 per mille, for which service the electromotive will have to develop 3,000 horse-power on the rails. Goods trains weighing up to 670 tons will run with a speed of from 27 to 28 kilomètres per hour, and have two electromotives, one in front and one in the rear, each rated at 2,800 horse-power. Passenger trains will be heated by steam, the boiler being carried in a special heating coach. Except for the stipulation that the traction must be single-phase at 15 frequency and a voltage of 7,500, which may eventually be raised to 15,000, no definite type of electromotive has as yet been selected, but there can be no doubt that several of the already existing types of mono-phase electromotive can be adapted to the special requirements of the Gothard line.

The following Report and Papers were then read :—

1. *Interim Report on Gaseous Explosions.*—See Reports, p. 166.

2. *On the Effect of Compression Ratio on the Efficiency of a Gas Engine. By* Professors G. ASAKAWA *and* J. E. PETAVEL.

The experiments were carried out on a 25-h.p. National gas engine working at normal speed. The load, speed, and number of missed explosions were kept constant, while the ratio of compression was varied by altering the length of the connecting rod.

Coal-gas was used, its calorific value being determined both by analysis and by direct measurement. The heat carried away by the jacket water and by the exhaust gases was carefully measured and a heat balance established.

The results may be summarised as follows :—

The brake horse-power at full power increases in the same proportion as the theoretical air efficiency, so that the ratio of the two or the relative efficiency remains constant at about 55 per cent. Under light loads the increase of frictional losses with high-compression ratios nearly counterbalances the gain in thermodynamic efficiency, and hence while the absolute efficiency remains constant the relative efficiency falls.

At all loads the mechanical efficiency is higher for low-compression ratios. At full loads it fell from 79 per cent. to 74 per cent.; as the compression ratio rose 3·7 to 5·6 at one quarter load it fell from 54 per cent. to 50 per cent. for the same change of compression ratio.

The indicated power at full load increases at a higher rate than that given by calculations based on the air standard and at light loads at the same rate; hence the relative indicated efficiency increases at full loads and remains constant at light loads.

Using gases of a lower calorific value of 520 B.T.U. per cubic foot at 32° F., the consumption at full power was 22 cubic feet per B.H.F. per hour with the lowest compression, and 18 with the highest.

Full numerical data together with a discussion of the results will shortly be published.

3. *Liquid, Solid, and Gaseous Fuels for Power Production. By* Professor F. W. BURSTALL, *M.A.*—See Appendix, p. 808.

FRIDAY, SEPTEMBER 12.

The following Papers were read :—

1. *The Internal Combustion Engine applied to Railway Locomotion. By* F. W. LANCHESTER.

In this paper it was pointed out that the steam locomotive, after having survived for nearly a century with all its essential features practically unchanged, appears to show signs that it is about to yield supremacy to other methods of traction. A brief review of the various tentative directions in which effort is being expended shows that the position of the steam locomotive is being assailed on the one hand by schemes of electrification, and on the other by the development of the internal combustion engine, and more particularly by self-propelled independent units—otherwise known as motor-coaches. It is the modern development of the motor-coach that formed the subject of the paper.

Various systems by which the internal combustion engine was applied to railway traction were discussed, and by process of elimination the author deduced that for the conditions of British railways, at least, the most promising solution is found in a straightforward piece of engineering, in which all the

main elements, the petrol-motor, the gear box, the jointed transmission-shaft, and the right-angle drive, also the auxiliary electrical equipment are taken *mutatis mutandis* from motor-car practice. It was pointed out that though the component parts of the railway coach thus constituted and the motor-car are analogous, there are certain functional differences, or differences in the object aimed at, which render considerable variations of method and proportion necessary.

The paper described in detail a recent development of the self-propelled railway coach in the form of a vehicle built by the Metropolitan Waggon Company and equipped with its power installation by the Daimler Company. The general lines of the coach—a 60-foot bogie—were described, and the installation was given as being furnished in duplicate, each power unit comprising a six-cylinder sleeve-valve Daimler engine of six-inch bore and six-inch stroke, a triple-tandem six-speed epicyclic gear-box, in which the speeds are grouped as three low-gear ratios, whose function is mainly in starting and giving high acceleration, and three high-gear ratios, which are exclusively used for running at speed. The whole of the gears are actuated by clutches of the magnetic type. The right-angle transmission is fitted to a prolongation to one of the bogie axles, and consists of a bevel drive, in which the pinion on the tail shaft gears simultaneously into two crown-wheels on the axle, an alternative dog-clutch being arranged to bring one or the other into positive connection. By this means the reversal of the car is effected.

The two units are disposed symmetrically on opposite sides of the vehicle, and drive on to opposite ends, so that the job is entirely symmetrical. The vehicle can be controlled from either end, drivers' cabins and duplicate controllers being fitted The electric equipment consists of dynamos coupled direct to the tail ends of the respective engine crank-shafts and an accumulator battery, and serves both for starting the engines and for lighting purposes and driving an electric air-compressor to operate the air-brake. Calculations were given as to the resistance and fuel consumption, &c., the paper being illustrated by diagrams and lantern slides.

2. *A New Type of Hydraulic Weighing Machine.* *By* H. S. Hele-Shaw, *LL.D., D.Sc., F.R.S., M.Inst.C.E.*

The object of this paper was to describe a new type of hydraulic weighing machine and to give a short account of the results obtained with it. In the first place it was pointed out that weighing machines are of two main types, viz. :—

(1) Suspended, or Crane Weighing Machines.
(2) Table, or Platform Weighing Machines.

The chief difficulties with hydraulic machines common to both the above types are two in number :—

The first and most serious results from the use of packing for the hydraulic pistons, or the employment of diaphragms.

The second is in connection with the recording gauge, or other contrivance, the indication of which is necessary to measure the weight being recorded; and beyond these two difficulties there is yet a third which is peculiar to the machine of the platform type, viz., the necessity of dealing with the number (generally four) of different pressures at different points of the table or platform.

The means by which in the new machine the first difficulty is overcome is by taking advantage of the modern development of grinding, by which accurately fitting cylindrical parts can be obtained at comparatively small cost, so that when oil is used as a fluid, cylinders and plungers can be employed to work together under very great pressures with comparatively small leakage, and with no appreciable friction.

It may be said at once that if the condition of the fit of the plunger and cylinder are such as to ensure a layer of oil between them, and thereby to avoid the friction which would otherwise occur between solid bodies in contact, there must inevitably be some slight leakage of the working fluid, and the chief feature

of the new machine is a device for dealing with this leakage. This device allows a certain period of time during which weighing can take place, and when the limit of this period is reached it is merely necessary to take off the weight, and pick it up again in order to restore the oil which has leaked away, and thus bring the machine to its normal condition. There are two cylinders which take the form of caps, and which work respectively on two plungers joined co-axially together. The two cylinders are slightly different in diameter, and consequently the co-axial plungers form one stepped plunger, which is really made in one piece, and resembles in effect the inner or solid portion of an ordinary stepped gauge.

The amount of the load is recorded by a pipe communicating with the gauge or its equivalent from the larger cylinder. The object of the small cylinder is as follows :—

The load is applied in such a way as to force the two cap cylinders together, and it is obvious that there must be a greater pressure per square inch in the cylinder of smaller diameter. If there were a direct connection between the two cylinders through the stepped plunger itself it is clear that the small cylinder would be forced at once against the end of the stepped plunger adjacent to it, all the oil passing into the larger cylinder. If, however, the communication between the two is cut off when a certain desired position is obtained, it is clear that the large cylinder will be kept relatively in that position to the end of the plunger adjacent to it until the oil is exhausted from the smaller cylinder—that is to say, the leakage between the end of the larger cylinder and the portion of the plunger working in it will be made up by the flow from the smaller cylinder.

Sooner or later, according to the design, the supply is exhausted into a common reservoir from both cylinders, and the recording portion ceases to act. The normal condition of the machine is then regained by the following contrivance :—

There is a spring between the cap of the smaller piston and the adjacent end of the stepped plunger There is also a small inlet valve communicating from the waste reservoir to the smaller cylinder. When the limit of weighing is reached the load is removed, and immediately the above spring forces out the smaller cap piston, filling it with oil. Upon the load being again applied, the pressure of oil in the small cylinder at once causes the plunger to travel to its limiting position in the large cylinder, thereby restoring the normal position of the contrivance It will be noted that the spring in the smaller plunger does not in any way come into the problem of the total amount of fluid pressure, and therefore does not in any way affect the accuracy of the machine, and merely operates to restore normal conditions.

With regard to the indicating portion of the machine, the hydraulic weighing machine lends itself to the employment if desired of a steelyard method of giving the results, though the indicator springs that can be used are now made of very great accuracy, and their reading can be relied upon, especially in cases such as the present one, where the temperatures are normal. It may further be pointed out that the use of oil has the great advantage of keeping the working pistons always in suitable conditions, and preventing any corrosion of the working parts.

The machine further can by a very simple process be put out of action when weighing is not required.

From observations already made with both the suspended and platform types of machines it is clear that very accurate movements of a passing load can be recorded, since the inertia of the system is very small, and shocks appear to have no injurious effect on the machine. As the plungers and pistons are submerged in oil, these parts can be made of cast iron and the whole machine produced at a very low cost.

3. *Aerial Propulsion of Barges on Canals. By* L. B. DESBLEDS.

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From observations already made with both the suspended and platform types of machines it is clear that very accurate movements of a passing load can be recorded, since the inertia of the system is very small, and shocks appear to have no injurious effect on the machine. As the plungers and pistons are submerged in oil, these parts can be made of cast iron and the whole machine produced at a very low cost.

3. *Aerial Propulsion of Barges on Canals.* *By* L. B. Desbleds.

4. *Catastrophic Instability in Aeroplanes.* *By* F. W. Lanchester.

Attention was called to a form of instability of a kind not previously investigated. The author bases his investigation (which is of a preliminary character) mainly on observations made in the course of his previous experimental work and mentioned in his 'Aerial Flight,' reading these in the light of some modern experiments on the pressure reaction of aerofoils, more particularly tests made in the National Physical Laboratory. The author takes as his starting point the ballasted plane, it being shown that this type of glider (in common with some other types) has a certain ambiguity in its flight path, its whole peripteral pressure system being liable to reversal as the results of aerial disturbances of quite minor degree. It was pointed out that types of gliding model having this property are unsuited to the purposes of aerial navigation, since in the event of a 'reversal' taking place an immediate and accelerated descent results of a character that can scarcely fail to bring disaster.

The conclusions formulated are that, although in absence of knowledge the design of a machine might easily be such that this form of instability would show itself, the avoidance of any danger is not difficult; briefly, the following points require to have due consideration :—

(*a*) The tail should be a directive rather than a weight-carrying organ, the construction of existing machines being criticised in this respect;

(*b*) The aspect ratio of the tail-plane should be high;

(*c*) The influence of the 'wash' as affecting the angle and behaviour of the tail-plane to receive proper consideration.

It was further pointed out that any model or machine that, with a single setting of its directive organs, is capable of flying either way up is liable to exhibit catastrophic instability, and must be considered dangerous.

In conclusion a few remarks were added on the subject of the flexibility of the sustaining and directive organs as bearing on the main subject of the paper.

5. *Domestic Electric Cooking, Heating, and Lighting. Results of One Year's Working.* *By* Professor J. T. Morris.

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6. *Note on Frictional Losses in Steam Pipes.* *By* Cecil H. Lander, *M.Sc., Assoc.M.Inst.C.E.*

The loss of pressure in a steam pipe is usually estimated by an expression of the form

$$p_1 - p_2 = \frac{4\,flv^2}{2\,gd}$$

in which different values of the constant f are used for different diameters of pipes. More accurate determinations referring to the flow of fluids carried out under more general conditions have shown that the exponent of the velocity is less than 2 and in the neighbourhood of 1·8.

The formula obtained from the theory of dimensions and deduced by Osborne Reynolds is

$$dp = \mathrm{K}\,d^{n-3}\,\mu^{2-n}\,\rho^{n-1}\,v^{n}\,dl$$

where dp is the drop of pressure along an element dl of the pipe, d the diameter, μ the viscosity, ρ the density and v the velocity. From this the following formula may be derived

$$p_1^{1.94} - p_2^{1.94} = \frac{\mathrm{S}\,\mu^{2-n}\,w^{n}}{(d^{3+n})}\left(1 - \frac{\lambda l}{2w}\right)l$$

where λ = actual weight of steam condensed per sec. per lin. foot of pipe

w = weight of mixture flowing through pipe in unit time.

S = Constant.

In any given set of experiments λ will be the condensation corresponding to the heat loss per lin. foot when the flow is zero, and will decrease as the velocity increases until the frictional heat is equal to that lost through the walls when λ will be zero. For velocities greater than this the steam initially dry will be superheated down the pipe and a modification of the above expression becomes necessary.

In the case of a covered pipe $\frac{\lambda l}{2w}$ is always small, and can be neglected without serious error.

A series of experiments have been carried out on a pipe $\frac{3}{4}$ ins. internal diameter and 75 feet long; the pressure drop, the heat lost through the walls, the velocity of flow, etc., were measured. The velocities were varied from 30 to 200 feet per sec., and the initial pressures from 9 to 215-lbs. absolute.

The results can be represented with considerable accuracy by

$$p_1^{1 \cdot 94} - p_2^{1 \cdot 94} = 79 \cdot 4\ w^{1 \cdot 82}$$

for the particular steel tube used, the pressures being in lbs. per square inch, and w being the weight flow in lbs. per minute.

The experimental work is still in progress, and the effect of diameter is being investigated.

7. *Bank Note Engraving.* *By* A. E. Bawtree, *F.R.P.S.*

It is universally admitted that geometrical engraving is ideal for bank-note work, since its regularity increases the difficulty of counterfeiting, unless the forger has in his possession suitable machinery.

The machinery in general use reached its present form nearly half a century ago, with the result that the forger has equipped himself as well as the bank-note engraver.

Intaglio plate printing has defied accurate reproduction till the year 1912, when a process was exhibited at the Royal Photographic Society which renders this class of work the easiest of all kinds of printing to copy in facsimile. This process calls for neither skill on the part of the operator, nor costly nor elaborate appliances.

Various systems of elaborate colour-ground have been tried upon bank-notes. Though these have in some cases successfully defied direct photographic reproduction, they have all failed, either because the forger knows all about the engraving machinery, or because the nature of all such grounds producible by the machinery hitherto available has necessarily exposed them to reproduction by a process in which the repeated sections are photographed separately and a paste-up of the complete design produced from these components by photo-lithography.

Figure studies, views, and other pictorial work possess no security, since their line structure is only obvious to an expert, and the forger can reproduce the tone values by ordinary photo-mechanical processes in common use.

It is therefore essential that security printing must be geometrical in character; it must be free from the characteristic repetition of sections produced by the pentagraph and transfer engraving process; the character of the engraved work must be unmistakably and completely different to that in which time and text-books have made the forger himself expert.

The new system of engraving, which has now been adopted by the Newfoundland Government, as well as some of the most prominent bankers for notes, and financiers for bonds, &c., is the only system that fulfils the above conditions. It also embodies numerous features of security which could not be incorporated in older methods of engraving, *e.g.* :—

1. While ordinary engravers' stock of sections is repeatedly used, sometimes upon photographically protected work, and at others for ornamental purposes, where the forger can easily photograph it, in the new system security and ornamental stock are kept apart.

2. Bond coupons cannot be adequately protected through the limitations of existing machinery, while the new system specially lends itself to the engraving of these awkward little notes.

3. A hidden design can be incorporated in the work and only rendered visible by means of a screen through which the banker can inspect it.

4. The new system produces incomparably more beautiful geometrical engraving than any of the older methods can accomplish.

MONDAY, SEPTEMBER 15.

Joint Discussion with Section A on the Investigation of Complex Stress Distribution.

The following Papers were read :—

1. *The Construction of Large Polarising Apparatus for Use in Lantern Projection Work. By* Professor E. G. COKER, *D.Sc.*—See p. 389.

2. *The Stress Distributions in Thick Cylinders and Rings. By* Professor E. G. COKER, *D.Sc.*

The difficulty of measuring experimentally the state of stress in thick cylinders and rings is well known, and it is important that the means employed shall give measurements at a point of a material.

An optical method of investigation with a transparent material affords a comparatively simple and accurate method of experiment for determining the directions and magnitudes of the principal stresses at any point of a ring constructed from a thick plate. The directions of principal stress at any point are determined from the lines of equal inclination obtained with plane polarised light, and the difference, $p-q$, of the principal stresses at the same point is obtained from observations of the double refraction effects produced when a beam of circularly-polarised light traverses the stressed object. The sum, $p+q$, of the principal stresses is also determined by measurements of the change in the thickness of the stressed object, using a delicate extensometer capable of detecting a change of half-a-millionth of an inch. These latter measurements are compared with the changes produced in the thickness of a simple tension or compression member of the same material as the object, and in this way the sum of the principal stresses is determined without further reference to the physical constants of the material.

These measurements of (a) the sum, (b) the difference, and (c) the directions of the principal stresses at a point taken as averages over the thickness of the plate afford a complete experimental solution of the distribution analogous to those obtained mathematically in problems of generalised plane stress.

The experimental methods are applicable to very complicated cases, and are described with reference to the stress distributions in thick cylinders and rings of various forms, with and without discontinuities. Special apparatus for applying and measuring loads and fluid pressures applied to rings and cylinders are also described and illustrated.

3. *The Stream-Line Flow of Solids. By* THOMAS REID.

The geometrical laws that govern the deformation of plastic materials are mainly based on assumptions made in connection with the experimental researches of the late M. Tresca. In his experiment on the formation of a jet by the plastic flow of lead from an orifice in the end of a cylindrical die-block from which the lead, in the form of a cylinder of superposed discs, was forced out by means of a piston subjected to pressure in a hydraulic press, the lead flows radially towards the axis of the cylinder, displacing a core, which forms the jet by the concentric contraction of the cylinder. The author pointed out that, although the lead under the particular conditions of the experiment

referred to must flow in that manner, because the cleavage planes between the discs produce discontinuity in the material in the direction of the axis of the cylinder, and thus prevent flow taking place in that direction, it does not follow that the flow of a *solid* cylinder of lead must be the same.

With the object of determining the nature of the flow of solids, the author carried out a series of experiments, which he believes prove that the flow in every case below a certain critical velocity consists of molecular irrotational and rotational motion, the direction of the flow being stream-line, and that the flow is steady, straight-line motion until the stream changes its course in converging towards the orifice, and in the case of the extrusion of solid lead from an orifice there is no radial flow or concentric contraction as has been assumed until the stream-lines begin to converge towards the orifice. In fact, the solid material behaves exactly as a noncomprehensible viscous fluid. When the motion is very slow the flow is perfectly stable, and when above a certain critical velocity eddies tend to form, and turbulent motion results, and the temperature of the material undergoing extrusion rises.

The method of carrying out the experiments was as follows: The various die-blocks were made in two halves, definitely registered, and strongly bolted together, and fitted with pistons, the sections of the die-blocks being parallel to the direction of flow. The lead cylinders for the experiments were similarly formed in two halves, which were compressed in the die-blocks by the pistons, with the orifice plugged so as to render the lead perfectly homogeneous and free from the possibility of local motion. The face of one of each pair of semi-cylindrical blocks thus formed was then grooved at regular distances apart by grooves parallel to their axes. Tin wires were then placed in the grooves, and the pairs of semi-cylinders again compressed in the die-block with the orifice plugged, which had the effect of fixing the wires securely in the grooves by compressing the lead round them, after which the plug was removed from the orifice, and the extrusion of the lead cylinder carried out. The compression and extrusion of the lead cylinders was done under the compression heads of a fifty-ton testing machine, which allowed stress-flow curves to be taken at various speeds of extrusion.

The tin wires retain their position in the lead blocks, and show clearly the direction and general conditions of flow.

The flow of lead in a cylinder with sudden concentric enlargement in the direction of flow, also the flow past a solid of revolution, was investigated, and in both cases the motion was found to be of stream-line order, as in the case of extrusion from an orifice. The effect of punching a solid block with and without shearing out the wad was also investigated, and the stream-line flow determined.

The behaviour of other metals under suitable conditions was investigated, and the same results were found as with the lead.

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4. *Note on the Strength of Free-ended Struts.* *By* ANDREW ROBERTSON, *M.Sc.*

This paper gave an account of experiments made on mild steel struts to ascertain the law of variation of strength with length when special precautions were taken to secure (*a*) axial loading, (*b*) straightness, (*c*) freedom of the ends from constraint.

The conclusions are :—

1. That Euler's law is followed down to the length for which the load per square inch given by this law is equal to the stress at yield.
2. That below this limit collapse occurs when the load per square inch is equal to the yield stress.
3. That for round struts of length less than five diameters there is no definite ultimate load. The transition from the elastic to the plastic state is marked not by collapse of the strut, but merely by a sudden deformation of appreciable magnitude.

In all the cases in which the collapsing load per square inch was equal to the yield stress the specimens were bent, and on relieving the load and again testing them they failed under a load smaller than the first collapsing load. This is

probably due to the existence in compression, as in tension, of a condition immediately after yield in which the stress that the material will sustain is less than that required to initiate the yield.

The effects of eccentricity of loading and initial curvature were investigated, and a number of tests of struts of ordinary commercial section compared with the theoretical results.

5. *Metals for Structures.* *By* A. T. Walmisley, *M.Inst.C.E.*

Birmingham from an early date has been recognised as one of the chief seats of industries in metals, and hence a paper which presents an opportunity to elicit a discussion upon some of the latest developments of various alloys used as constructive materials appears suitable for a meeting of the Engineering Section. Such alloys are not mere mechanical mixtures, but homogeneous combinations, secured by fusion, possessing distinguishing qualities for special purposes.

Copper possesses the element of conductivity. It is always economical to use the purest copper obtainable commercially, especially for electrical purposes. In contact with iron it is inimical to the iron. Hence roofs are boarded. A layer of felt will serve as a separator, care being taken in the attachment of bolts to allow no immediate contact between iron and copper.

Zinc is applied for coverings. Galvanised sheets can be tested with sulphate of copper, which will adhere to any exposed surface of the iron not coated with zinc. The durability of zinc depends mainly on the spelter from which it is made. A covering of zinc is better adapted to resist the attacks of a vitiated atmosphere than galvanised iron, which provides simply an exterior coating.

Lead has no elasticity, but is useful for girder seatings, where the weight is sufficient to crush the lead so as to produce uniformity of pressure upon the bearing. It is also serviceable for roof coverings and for flashings.

Brass, consisting of copper and zinc, is employed for lubricators and pumps, while Muntz's metal—also an alloy of copper and zinc—has superseded copper for sheathing vessels.

Manganese bronze, an alloy of copper and ferro-manganese, is serviceable for propeller blades, on account of its toughness; and ordinary bronze—an alloy of copper and tin—is found to possess sufficient fluidity for satisfactory melting, combined with slightness of contraction on solidifying.

Phosphor bronze, by the addition of phosphorus, excels ordinary bronze in hardness, density, and tensile strength, and is used for friction bearings, especially when liable to shock; also for sliding surfaces in the case of steel shafts, as a steel or wrought-iron shaft would be liable to grip a cast iron bearing.

Gunmetal, another alloy of copper and tin, takes its name from its employment as the metal from which large guns were formerly made, while bell-metal and delta-metal also possess characteristics described in the paper.

When one metal less oxidisable than another comes in contact galvanic action may be set up. In the case of mild steel and wrought iron in metallic contact the steel may oxidise at the expense of the iron. Iron rivets have been found to become slack in steel plates without any special wasting in the steel plates, while the iron has wasted somewhat.

The durability of materials is one of the leading questions of the day.

TUESDAY, SEPTEMBER 16.

The following Papers were read :—

1. *Notes on an Engineering Theory of the Gyrostat.* *By* J. W. Gordon.

2. *Exposure Tests of Copper, Commercial Aluminium, and Duralumin.* *By* Professor Ernest Wilson.

These are a continuation of tests upon the influence of exposure in London on the electrical conductivity of light aluminium alloys, reports of which have

been made from time to time to the British Association. Each specimen is in the form of wire 0·126 inch diameter and 70 feet long; and the figures obtained after two years' exposure are:—

	Percentage increase of electrical resistance taken on value in 1911 at 15° C.
High conductivity copper	2·0
Commercial aluminium	4·4
Duralumin	8·2

Duralumin is a copper-manganese-magnesium alloy of high tensile strength, and exposure has apparently made it more brittle.

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3. *The Nature of the Electromagnetic Waves employed in Radiotelegraphy and the Mode of their Propagation. By* Professor G. W. O. Howe, *M.Sc.*

A very clear conception of the nature of the electro-magnetic waves employed in radiotelegraphy can be obtained by considering those electro-magnetic waves which exist in the space between the two conductors of a single-phase transmission line. If the conductors are flat, parallel strips, close together, and connected at the sending end to the terminals of an alternator, there is a certain value of the non-inductive load at the receiving end which will absorb the arriving energy without any reflection. Under these conditions the current and voltage are in phase all along the line, and the same is true if the line is assumed to be of infinite length. Line resistance and leakage are assumed to be negligible. It follows from this that the electric and magnetic fields at any point have their maximum values at the same moment. Instead of two parallel strips transmitting energy in one direction, two parallel discs of infinite extent can be imagined with the alternating P.D. applied between their centres. Energy would then be transmitted radially in all directions in the plane between the discs. The earth could take the place of the lower disc, while the upper one could be represented by a conducting horizontal plane some distance above the earth. The waves produced would be truly cylindrical, whereas those employed in radio-telegraphy are spherical. If, now, the upper disc is replaced by an inverted conducting cone of infinite extent, with its apex almost in contact with the earth, the alternating P.D. being applied between the apex and the earth, the electro-magnetic waves will be almost identical with those employed in radiotelegraphy and will vary in the same way with the distance from the sending station. This imaginary multi-directional transmission line, consisting of a lower plane (the earth) and an inverted cone, lends itself to simple calculation, because, like an ordinary transmission line, and unlike the two parallel discs, it has a constant inductance and capacity per mile. It can be shown that if the angle between the cone and the earth is 35 degrees, the relations between the magnetic and electric fields near the earth's surface and the total energy radiated are identical with those existing in the ordinary radio-telegraphic wave. As in the transmission line already considered, the current and P.D. will be in phase at every point, and therefore, contrary to the usually accepted view, the horizontal magnetic field and the vertical electric field due to a sending antenna are not 90 degrees out of phase but are approximately in phase, except in the immediate neighbourhood of the antenna. This also follows from the fundamental equations of a progressive, as distinct from a stationary, electro-magnetic wave.

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4. *Atmospheric Refraction and Absorption as affecting Transmission in Wireless Telegraphy. By* Dr. W. H. Eccles.

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5. *Effect of Atmospheric Conditions on the Strength of Signals received at Liverpool from Paris and some other places, together with an Account of the Diurnal Variation in the Energy received. By* Professor E. W. Marchant, *D.Sc.*

Measurements have been made over a considerable period of time, but those described herein deal mainly with observations during the month of July. The

most accurate observations have been obtained with signals sent out by the observatory at the Eiffel Tower at 10.45 A.M. and 11.45 P.M. The method adopted in the earlier tests was to use a 'Perikon' detector in series with galvanometer and telephones, the measurement of strength being made by the cumulative deflection due to a series of known signals. This method was not found satisfactory with the Paris signals for which the antenna current used was known, and in the later tests an Einthoven string galvanometer has been employed by which the strength of signal for each individual spark at Paris could be observed to within $\pm$ 5 per cent. The results obtained show that there is a maximum variation from 0·6 to 1·3 in the strength of the signals received on different days in the same month; the average strength of signal being assumed to be 1·1, and that the current received on a fine, clear night is about 1·7 times as strong as that received in the day-time.

Although no certain relationship can yet be regarded as established between the strength of a signal and the weather conditions at the sending and receiving stations, so far, observation has shown that rain in Paris always corresponds with a diminution in strength of received signal. In one case, with a wind of six metres per second velocity, blowing in a N.W. direction, the signal-strength fell to half its normal value. The most favourable condition for signalling appears to be a cloudy sky at both sending and receiving stations, the signals being weaker when the sky is clear or covered with light clouds. Rain at the receiving station appears to have a comparatively small influence on the strength of the received signals.

The result of a set of special signals sent from the Eiffel Tower on the evening of Saturday, July 26, 1913 (by the courteous arrangement of Comm. Ferrié), at intervals of 30 minutes, between 7 and 10 P.M. (which includes the time of sunset), shows that the increase in strength of night signals occurs about three-quarters of an hour after sunset, there being a sudden increase in strength of about 70 per cent. This change is quite sudden, there being comparatively little alteration in signal-strength until darkness has set in, and no perceptible increase in strength afterwards. There appears to be some evidence that signals are slightly stronger just after sunset than during normal night conditions.

6. *Short Heat Tests of Electrical Machines. By* W. R. COOPER, *M.A., B.Sc.*

Tests of dynamo-electric machinery are generally carried out extending over six hours in order to determine the maximum temperature rise. Suggestions have been made that such tests might be considerably shortened by assuming that the curve of temperature rise is a logarithmic curve. The author gives a brief account of the methods that have been proposed, and points out that the 'thermal time constant,' on which the behaviour of a body in heating and cooling largely depends, should be found most easily, and under less complex conditions, from the cooling curve. In order to test the applicability of the various methods, tests were made upon a 5 kw. motor-driven dynamo. The curves of temperature rise were found to be fairly logarithmic. The usual method of running a machine on test is to run on constant output with constant voltage, which necessitates increasing the input to the field coils as their resistance rises. A truly logarithmic curve can only be expected if the input of heat is at a constant rate, so that a better result would be expected if a machine were tested with constant input to the field coils, the output of the machine being constant but at varying voltage. Actually this method of testing was not found to give an improved result. Graphical methods appear to give better results than formulæ, as the latter are very sensitive to small errors in the data. In any case only certain portions of the temperature-rise curve should be used, and any formulæ depending on the initial rate of temperature-rise should be avoided, as this is difficult of exact determination. The curve of cooling has certain advantages; but only a small portion of it seems suitable for graphically determining the thermal time constant, and this quantity can be derived much more readily from the time taken for a certain percentage drop of temperature-rise. In the results given there is better agreement between the values found for the thermal time constant than for the maximum temperature-

rise. It is suggested that a fair approximation to the maximum temperature-rise can often be obtained by testing for a time equal to, say, $1\frac{1}{4}$ times the thermal time constant, deducing the value of this constant from the cooling curve, and thence the maximum temperature-rise from the heating curve.

WEDNESDAY, SEPTEMBER 17.

The following Papers were read :—

1. *On Landslides accompanied by Upheaval in the Culebra Cutting of the Panama Canal. By* VAUGHAN CORNISH, *D.Sc., F.R.G.S.*

The author visited the Panama Canal works in 1907, 1908, 1910, and 1912.

Throughout a distance of about three miles between Empire and Culebra, in the Culebra Cut, the bottom rock has for four years past bulged up in many places to a height of 20 feet and more. The bulging is accompanied or followed by subsidence of the bank behind. Both the convex hump below and the concave subsidence above are crevassed, but the surface of the ground between sometimes remains unbroken. It was unanimously decided by the American and European members of the Board of Consulting Engineers appointed in 1905 that the sides of the Cut should be given a slope of three vertical on two horizontal, and be cut in terraces, and it was considered that they would be stable with a depth of excavation of 245 feet at the position of 'mile 36,' which is in the section above referred to, where the worst bulgings have occurred. At this point the French excavated to a depth of 45 feet on the centre line between 1883 and 1889. In the years which followed, the slopes suffered little from superficial weathering. The American Commission commenced excavation in 1904, and carried it to a total depth of 65 feet by June 1909, by which time upheaval commenced on a small scale. During the twelve months ending June 30, 1910, the bottom was lowered a further 35 feet to a total depth of 100 feet, and the terraces were cut away, a continuous slope being substituted. Bulging of the bottom and collapse of the sides occurred on a great scale throughout this year. During the next year, ending June 30, 1911, the slopes were much flattened, and were again cut into terraces, and the blasting charges were reduced. Towards the end of the twelve months the upheavals were few and small, but it must be observed that the lowering during the year amounted to only 15 feet. The next year, ending June 30, 1912, was that of the author's latest inspection of the Cut. During this time the smaller blasting charges were used, the terraced form of side was maintained, and the work was favoured by dry weather, and the general slope had been reduced to about one vertical on three horizontal. The lowering of the bottom by a further 33 feet to a total depth of 148 feet was, however, accompanied by a renewal of upheavals on a large scale. The evidence is that they occur owing to the crushing and dry flow of thin strata, or seams, of weak rock—*e.g.*, lignite—underlying the bottom. The question is: Why was not this foreseen either by engineers or geologists, although numerous borings had been made and the country geologically surveyed? The author is of opinion that the mistake was mainly due to disregard of chemical considerations. The cutting here is through horizontally bedded rocks composed of fragments ejected from a volcano and deposited in a shallow sea in Tertiary times. Some of the strata, or seams, disintegrate rapidly under the physical, and, more particularly, the chemical action of rainwater; to which they are now for the first time exposed. With such disintegration going on a collapse of the banks would necessarily occur, but the frequent occurrence of large upheavals of the bottom is due, in the author's opinion, to stratification.

The process occurs even under natural conditions. Rocks occur in beds which are very thin in proportion to their extent, and are therefore easily deformed if unequally supported. When the material of a lower stratum has any degree of fluidity, and the pressure upon it is different at different places, there is a flow from the place of greater to that of less pressure, and the superincumbent rock is let down in the former and bulged up in the latter place.

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2. *Birmingham Snow Hill Station Alterations.* *By* F. Gleadow, *M.Inst.C.E., and* C. E. Shackle, *Assoc.M.Inst.C.E.*

The railway station buildings and platforms recently removed from this site were erected in 1870 on the site of a still older station. The two principal platforms were originally in direct connection with the streets on either side. The platforms and railway lines between the buildings on either side were covered with an iron roof, with crescent-shaped girders of about 92 feet span. The site of the new station, as well as that of the old, is bounded on the south by Colmore Row, on the east by Snow Hill, and on the west by Livery Street. The building adjoining Colmore Row, formerly an hotel, is now converted into offices, restaurant, etc., and an entrance has been made through it for foot-passengers, leading to the high level booking-hall. Entrances and exits for carriages are provided on the Livery Street and Snow Hill sides. From the above mentioned booking-hall corridors terminating in stairways lead down to the two main platforms, and lifts are provided for dealing with passengers' luggage.

The roof over the main entrance and circulating area consists of steel arched ribs of about 94 feet span, with glazed screens at the east and west sides. Over the main platforms and buildings thereon, the roof is of the 'ridge and furrow' type, carried on steel girders, and resting on steel columns, these being cased, for appearance' sake, with cast iron. Beyond this length of platform, where the width of platform becomes much less, the type of roof is again changed to one generally known as the 'umbrella' type, on account of its being supported by single steel columns, anchored below platform-level into concrete blocks.

The buildings have been freely treated from an architectural point of view, the material used being principally glazed red bricks, with buff-coloured terra-cotta dressings externally, and Carrara-ware dressings internally.

The steelwork in the roof is designed to withstand a wind-pressure of 40 lb. over the whole surface, and any individual portion of it to withstand a local gust of 56 lb. to the square foot. Under no conditions can any of the steelwork be stressed to over six tons to the square inch in tension, or five tons in compression. The pressure upon the base of any foundation does not exceed three and three-quarter tons. The whole of the steelwork has been made by an open-hearth process.

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3. *Harbour Projections and their Effect upon the Travel of Sand and Shingle.* *By* Ernest R. Matthews, *F.R.S.E., A.M.Inst.C.E.*

The author pointed out that any seaward projection on a coast, whether it be in the form of a groyne extending merely to LWOT or LWOST, a breakwater, a harbour-arm projection 1,000 feet or more, or a promontory such as Flamborough Head or Spurn, extending seaward some miles, has the effect of arresting more or less, according to the magnitude of the projection, the travel of the sand and shingle on such coast. In the case of harbour projections run out at right angles to the coast-line this obstruction, especially on a sandy coast, impounds the travelling material on one side of the harbour, and often causes alarming erosion on the other. He gave excellent examples of this in the case of the Yarmouth, Shoreham, Lowestoft, and Madras harbours, at each of which millions of tons of sand (except in the case of Shoreham, where it is shingle), representing acres in area, are being held up by the harbour piers. The sea-front at Yarmouth may be said to have extended seaward during the past half-century an average of 300 feet, due almost entirely to the construction of the harbour; while at Madras 650 million cubic feet of sand has accreted on the south side of the harbour within a distance of three miles of the harbour, and 450 million cubic feet of land has been eroded on the north side within a similar distance, and the authorities there are now contemplating an extension of the harbour seaward at a huge cost. They consider it is necessary to do this in order to reduce the extent of the silting up of the harbour. The author referred to the Newhaven, Bridlington, and Whitby harbours, and that at Hastings, which is only partially constructed, and described their effect upon the coast. He also described the effect upon the coast of headlands which run out at approximately right angles with the coast, and those which form an obtuse angle with the coast.

He suggested that the question will naturally be asked: What is the remedy or partial remedy for this trapping of the travelling sand and corresponding erosion on the leeward side of a harbour? and explained that previously the only method of escaping from the impounded material seems to have been to periodically extend the arm of the harbour further seaward, as proposed for Madras. This meant a tremendous cost, and the results were often not satisfactory, for as the pier was advanced the shore also advanced. It had been suggested that instead of doing this openings should be left through the shore ends of the harbour arms for the sand to pass through; but this suggestion was not practicable, for immediately the travelling material passed through the opening the wave behind it did not possess sufficient force to move the material through, especially where the width of the harbour was considerable.

The author suggested that in order to modify this trapping of the sand the ground plan of the harbour, instead of showing the piers to run out at right angles to the coast, or approximately so, should show that on the side facing the direction of the travelling material to project from the coast at an angle of 45°, the additional area thereby enclosed by the harbour piers could be utilised, among other purposes, for that of wharfage. The travelling material would, he stated, pass around the harbour projection if the plan of the harbour was on these lines, and would supply the coast on the lee side of the harbour with a natural protection of sand and shingle.

He illustrated the various points referred to by numerous diagrams and photos, and stated that in arriving at his conclusions he carried out various experiments, which he described in the paper. He made the suggestion that where it can be proved that erosion has occurred, and is still taking place, owing to the projection of harbour piers, or the lengthening of such piers, or the construction of a spur breakwater from such piers, the harbour authorities should be called upon to contribute towards the cost of the protection of such a coast as far as the affected area is concerned. He also suggested that in the granting of powers by Parliament for the construction of new harbours, it should be made compulsory that contributions shall be made towards the cost of the prevention of erosion, where it can be proved later that protection works are necessary in consequence of such harbour projections.

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4. *The Transport and Settlement of Sand in Water, and a Method of Exploring Sand Bars. By* Dr. John S. Owens, *A.M.Inst.C.E., F.G.S.*

This paper, illustrated by experiments, dealt with certain phenomena accompanying the movement of sand in water. Sand ripples were shown travelling under the influence of a current. The grains being swept by the current from the back of the ripple and deposited on its face, the ripple-form thus moved forward with the current by a process of erosion of its back and accretion of its face. This was demonstrated by means of a trough with semi-circular ends and a longitudinal partition in the middle, thus forming two channels. The water was made to circulate up one channel and down the other, and the movements of the ripples were seen on the sand forming the bottom.

The formation of quicksands was illus'rated by means of a tank containing ordinary sea-sand, and it was shown that when water was caused to flow upwards through the sand the latter acquired all the properties of a quicksand and swallowed heavy bodies placed thereon.

The effect of obstacles lying on a sandy bed in the path of a current was demonstrated by means of a model. Stones and models of piles were placed on sand in the path of a current in a small tank, and localised erosion around the obstacles resulted in each case. This was shown to be due to the deflection and increased local velocity of the current.

The curious effect of suspended matter on the specific gravity of water was illustrated by means of a glass cylinder containing water in which sand was shaken up; it was shown that, while the sand was suspended, the specific gravity measured by a floating hydrometer was raised above that of water. The influence of such a rise in specific gravity in increasing the intensity of impact of the water and consequently its erosive power was indicated.

A tall glass tube filled with water was exhibited; in this bodies of different shape were allowed to sink; in every case, whether discs, rectangular plates or rods, the bodies settled in the position offering the greatest resistance to movement. It was shown that this property might result in more rapid settlement in running than in still water, and also account for a cleavage in sedimentary rocks.

A model of an instrument for exploring sand-bars and river-beds was shown. It consisted of two tubes arranged concentrically, connected at the top, but separated at the bottom. A cock-and-hose attachment was fixed on the upper end of the inner tube, and a second cock, with a spout, communicated with the top of an annular space between the two tubes. At the bottom the inner tube ended a short distance above the end of the outer tube. Water, if forced down the inner tube, must pass out at the bottom when the cock to the annular space is closed; in this case the instrument sinks if placed on a sandy bottom. When at any desired depth the cock to the annular space is opened the water returns up the outer tube, carrying a sample of the sand with it, and delivering the sample from the spout. By means of this instrument the depth and nature of bars and shoals may be easily ascertained.

Section H.—ANTHROPOLOGY.

President of the Section.—Sir Richard Temple, Bart., C.I.E.

THURSDAY, SEPTEMBER 11.

The President delivered the following Address:—

Administrative Value of Anthropology.

The title of the body of which those present at this meeting form a section is, as all my hearers will know, the British Association for the Advancement of Science, and it seems to me therefore that the primary duty of a Sectional President is to do what in him lies, for the time being, to forward the work of his Section. This may be done in more than one way: by a survey of the work done up to date and an appreciation of its existing position and future prospects, by an address directly forwarding it in some particular point or aspect, by considering its applicability to what is called the practical side of human life. The choice of method seems to me to depend on the circumstances of each meeting, and I am about to choose the last of those above mentioned, and to confine my address to a consideration of the administrative value of anthropology, because the locality in which we are met together and the spirit of the present moment seem to indicate that I shall best serve the interests of the Anthropological Section of the British Association by a dissertation on the importance of this particular science to those who are or may hereafter be called upon to administer the public affairs of the lands in which they may reside.

I have to approach the practical aspect of the general subject of anthropology under the difficulty of finding myself once more riding an old hobby, and being consequently confronted with views and remarks already expressed in much detail. But I am not greatly disturbed by this fact, as experience teaches that the most effective way of impressing ideas, in which one believes, on one's fellow man is to miss no opportunity of putting them forward, even at the risk of repeating what may not yet have been forgotten. And as I am convinced that the teachings of anthropologists are of practical value to those engaged in guiding the administration of their own or another country, I am prepared to take that risk.

Anthropology is, of course, in its baldest sense the study of mankind in all its possible ramifications, a subject far too wide for any one science to cover, and therefore the real point for consideration on such an occasion as this is not so much what the students of mankind and its environments might study if they chose, but what the scope of their studies now actually is, and whither it is tending. I propose, therefore, to discuss the subject in this limited sense.

What then is the anthropology of to-day, that claims to be of practical value to the administrator? In what directions has it developed?

Perhaps the best answer to these questions is to be procured from our own volume of 'Notes and Queries on Anthropology,' a volume published under an

arrangement with the Royal Anthropological Institute for the British Association. This volume of 'Notes and Queries' has been before the public for about forty years, and is now in the fourth edition, which shows a great advance on its predecessors and conforms to the stage of development which the science has reached up to the present time.

The object of the 'Notes and Queries' is stated to be 'to promote accurate anthropological observation on the part of travellers (including all local observers) and to enable those who are not anthropologists themselves to supply information which is wanted for the scientific study of anthropology at home.' So, in the heads under which the subject is considered in this book, we have exhibited to us the entire scope of the science as it now exists. These heads are (1) Physical Anthropology, (2) Technology, (3) Sociology, (4) Arts and Sciences. It is usual, however, nowadays to divide the subject into two main divisions—physical and cultural anthropology.

Physical Anthropology aims at obtaining 'as exact a record as possible of the structure and functions of the human body, with a view to determining how far these are dependent on inherited and racial factors, and how far they vary with environment.' This record is based on two separate classes of physical observation: firstly on descriptive characters, such as types of hair, colour of the eyes and skin, and so on, and actual measurement; and secondly on attitudes, movements, and customary actions. By the combined study of observations on these points physical heredity is ascertained, and a fair attribution of the race or races to which individuals or groups belong can be arrived at.

But anthropology, as now studied, goes very much further than inquiry into the physical structure of the human races. Man, 'unlike other animals, habitually reinforces and enhances his natural qualities and force by artificial means.' He does, or gets done for him, all sorts of things to his body to improve its capacities or appearance, or to protect it. He thus supplies himself with sanitary appliances and surroundings, with bodily ornamentation and ornaments, with protective clothing, with habitations and furniture, with protection against climate and enemies, with works for the supply of water and fire, with food and drink, drugs and medicine. And for these purposes he hunts, fishes, domesticates animals, and tills the soil, and provides himself with implements for all these, and also for defence and offence, and for the transport of goods, involving working in wood, earth, stones, bones, shells, metals and other hard materials, and in leather, strings, nets, basketry, matting and weaving, leading him to what are known as textile industries. Some of this work has brought him to mine and quarry, and to employ mechanical aids in the shape of machinery, however rude and simple. The transport of himself and his belongings by land and water has led him to a separate set of industries and habits: to the use of paths, roads, bridges, and halting places, of trailers, sledges, and wheeled vehicles; to the use of rafts, floats, canoes, coracles, boats, and ships, and the means of propelling them, poles, paddles, oars, sails, and rigging. The whole of these subjects is grouped by anthropologists under the term Technology, which thus becomes a very wide subject, covering all the means by which a people supplies itself with the necessaries of its mode of livelihood.

In order to successfully carry on what may be termed the necessary industries or even to be in a position to cope with them, bodies of men have to act in concert, and this forces mankind to be gregarious, a condition of life that involves the creation of social relations. To understand, therefore, any group of mankind, it is essential to study Sociology side by side with Technology. The subjects for inquiry here are the observances at crucial points in the life history of the individual—birth, puberty, marriage, death, daily life, nomenclature, and so on; the social organisation and the relationship of individuals. On these follow the economics of the social group, pastoral, agricultural, industrial, and commercial, together with conceptions as to property and inheritance (including slavery), as to government, law and order, politics and morals; and finally the ideas as to war and the external relations between communities.

We are still, however, very far from being able to understand in all their fulness of development even the crudest of human communities, without a further inquiry into the products of their purely mental activities, which in the 'Notes and Queries' are grouped under the term 'Arts and Sciences.' Under

this head are to be examined, in the first place, the expression of the emotions to the eye by physical movements and conditions, and then by gestures, signs and signals, before we come to language, which is primarily expressed by the voice to the ear, and secondarily to the eye in a more elaborate form by the graphic arts—pictures, marks and writing. Man further tries to express his emotions by what are known as the Fine Arts; that is by modifying the material articles which he contrives for his livelihood in a manner that makes them represent to him something beyond their economic use—makes them pleasant, representative or symbolical—leading him on to draw, paint, enamel, engrave, carve, and mould. In purely mental efforts this striving to satisfy the artistic or æsthetic sense takes the form of stories, proverbs, riddles, songs, and music. Dancing, drama, games, tricks and amusements are other manifestations of the same effort, combining in these cases the movements of the body with those of the mind in expressing the emotions.

The mental processes necessary for the expression of his emotions have induced man to extend his powers of mind in directions now included in the term 'Abstract Reasoning.' This has led him to express the results of his reasoning by such terms as reckoning and measurement, and to fix standards for comparison in such immaterial but all essential matters as enumeration, distance, surface, capacity, weight, time, value and exchange. These last enable him to reach the idea of money, which is the measurement of value by means of tokens, and represents perhaps the highest economic development of the reasoning powers common to nearly all mankind.

The mental capacities of man have so far been considered only in relation to the expression of the emotions and of the results of abstract reasoning; but they have served him also to develop other results and expressions equally important, which have arisen out of observation of his surroundings, and have given birth to the Natural Sciences: astronomy, meteorology, geography, topography and natural history. And further they have enabled him to memorise all these things by means of records, which in their highest form have brought about what is known to all of us as history, the bugbear of impulsive and shallow thinkers, but the very backbone of all solid opinion.

The last and most complex development of the mental processes, dependent upon all the others according to the degree to which they themselves have been developed in any given variety of mankind, is, and has always been, present in every race or group on record from the remotest to the most recent time in some form or other and in a high degree. Groups of men observe the phenomena exhibited by themselves or their environment, and account for them according to their mental capacity as modified by their heredity. Man's bare abstract reasoning, following on his observation of such phenomena, is his philosophy, but his inherited emotions influence his reasoning to an almost controlling extent and induce his religion, which is thus his philosophy or explanation of natural phenomena as effected by his hereditary emotions, producing that most wonderful of all human phenomena, his belief. In the conditions, belief, faith, and religion must and do vary with race, period and environment.

Consequent on the belief, present or past, of any given variety of mankind, there follow religious practices (customs as they are usually called) based thereon, and described commonly in terms that are familiar to all, but are nevertheless by no means even yet clearly defined: theology, heathenism, fetishism, animism, totemism, magic, superstition, with soul, ghost, and spirit, and so on, as regards mental concepts; worship, ritual, prayer, sanctity, sacrifice, taboo, etc., as regards custom and practice.

Thus have the anthropologists, as I understand them, shown that they desire to answer the question as to what their science is, and to explain the main points in the subject of which they strive to obtain and impart accurate knowledge based on scientific inquiry: that is, on an inquiry methodically conducted on lines which experience has shown them will lead to the minimum of error in observation and record.

I trust I have been clear in my explanation of the anthropologists' case, though in the time at my disposal I have been unable to do more than indicate the subjects they study, and have been obliged to exercise restraint and to employ condensation of statement to the utmost extent that even a long experience in exposition enables one to achieve. Briefly, the science of anthro-

pology aims at such a presentation and explanation of the physical and mental facts about any given species or even group of mankind as may correctly instruct those to whom the acquisition of such knowledge may be of use. In this instance, as in the case of the other sciences, the man of science endeavours to acquire and pass on abstract knowledge, which the man of affairs can confidently apply in the daily business of practical life.

It will have been observed that an accurate presentation of the physical and mental characteristics of any species of mankind which it is desired to study is wholly dependent on accurate inquiry and report. Let no one suppose that such inquiry is a matter of instinct or intuition, or that it can be usefully conducted empirically or without due reference to the experiences of others; in other words without sufficient preliminary study. So likely indeed are the uneducated in such matters to observe and record facts about human beings inaccurately, or even wrongly, that about a fourth part of the 'Notes and Queries' is taken up with showing the inquirer how to proceed, and in exposing the pitfalls into which he may unconsciously fall. The mainspring of error in anthropological observation is that the inquirer is himself the product of heredity and environment. This induces him to read himself, his own unconscious prejudices and inherited outlook on life, into the statements made to him by those who view life from perhaps a totally different and incompatible standpoint. To the extent that the inquirer does this, to that extent are his observations and report likely to be inaccurate and misleading. To avoid error in this respect, previous training and study are essential, and so the 'Notes and Queries on Anthropology', a guide compiled in co-operation by persons long familiar with the subject, is as strong and explicit on the point of how to inquire as on that of what to inquire about.

Let me explain that these statements are not intended to be taken as made *ex cathedrâ*, but rather as the outcome of actual experience of mistakes made in the past. Time does not permit me to go far into this point, and I must limit myself to the subject of Sociology for my illustration. If a man undertakes to inquire into the social life of a people or tribe as a subject apart, he is committing an error, and his report will almost certainly be misleading. Such an investigator will find that religion and technology are inextricably mixed up with the sociology of any given tribe, that religion intervenes at every point not only of sociology but also of language and technology. In fact, just as in the case of all other scientific research, the phenomena observable by the anthropologist are not the result of development along any single line alone, but of a progression in a main general direction, as influenced, and it may be even deflected, by contact and environment.

If, again, the inquirer neglects the simple but essential practice of taking notes, not only fully, but also immediately or as nearly so as practicable, he will find that his memory of facts, even after a short time, has become vague, inexact, and incomplete, which means that reports made from memory are more likely to be useless than to be of any scientific value. If voluntary information or indirect and accidental corroboration are ignored, if questions are asked and answers accepted without discretion, if exceptions are mistaken for rules, then the records of an inquiry may well mislead and thus become worse than useless. If leading or direct questions are put without due caution, and if the answers are recorded without reference to the natives' and not the inquirer's mode of classifying things, crucial errors may easily arise. Thus, in many parts of the world, the term 'mother' includes all female relatives of the past or passing generation, and the term 'brother' the entire brotherhood. Such expressions as 'brother' and 'sister' may and do constantly connote relationships which are not recognised at all amongst us. The word 'marriage' may include 'irrevocable betrothal,' and so on; and it is very easy to fall into the trap of the mistranslation of terms of essential import, especially in the use of words expressing religious conceptions. The conception of godhead has for so long been our inheritance that it may be classed almost as instinctive. It is nevertheless still foreign to the instincts of a large portion of mankind.

If also, when working among the uncultured, the inquirer attempts to ascertain abstract ideas, except through concrete instances, he will not succeed in his purpose for want of representative terms. And lastly, if he fails to project himself sufficiently into the minds of the subjects of inquiry, or to

respect their prejudices, or to regard seriously what they hold to be sacred, or to keep his countenance while practices are being described which to him may be disgusting or ridiculous—if indeed he fails in any way in communicating to his informants, who are often super-sensitively suspicious in such matters, the fact that his sympathy is not feigned—he will also fail in obtaining the anthropological knowledge he is seeking. In the words of the 'Notes and Queries' on this point, 'Nothing is easier than to do anthropological work of a certain sort, but to get to the bottom of native customs and modes of thought, and to record the results of inquiry in such a manner that they carry conviction, is work which can be only carried out properly by careful attention.'

The foregoing considerations explain the scope of our studies and the requirements of the preliminary inquiries necessary to give those studies value. The further question is the use to which the results can be put. The point that at once arises here for the immediate purpose is that of the conditions under which the British Empire is administered. We are here met together to talk scientifically, that is, as precisely as we can: and so it is necessary to give a definition to the expression 'Imperial Administration,' especially as it is constantly used for the government of an empire, whereas in reality it is the government that directs the administration. In this address I use the term 'administration' as the disinterested management of the details of public affairs. This excludes politics from our purview, defining that term as the conduct of the government of a country according to the opinions or in the interests of a particular group or party.

Now in this matter of administration the position of the inhabitants of the British Isles is unique. It falls to their lot to govern, directly or indirectly, the lives of members of nearly every variety of the human race. Themselves Europeans by descent and intimate connection, they have a large direct interest in every other general geographical division of the world and its inhabitants. It is worth while to pause here for a moment to think, and to try and realise, however dimly, something of the task before the people of this country in the government and control of what are known as the subject races.

For this purpose it is necessary to throw our glance over the physical extent of the British Empire. In the first place, there are the ten self-governing components of the Dominion of Canada and that of Newfoundland in North America, the six Colonial States in the Commonwealth of Australia, with the Dominion of New Zealand in Australasia, and the four divisions of the Union of South Africa. All these may be looked upon as indirectly administered portions of the British Empire. Then there is the mediatised government of Egypt, with its appanage, the directly British administered Sudan, which alone covers about a million square miles of territory in thirteen provinces, in Northern Africa. These two areas occupy, as it were, a position between the self-governing and the directly-governed areas. Of these, there are in Europe Malta and Gibraltar, Cyprus being officially included in Asia. In Asia itself is the mighty Indian Empire, which includes Aden and the Arabian Coast on the West and Burma on the East, and many islands in the intervening seas, with its fifteen provinces and some twenty categories of Native States 'in subordinate alliance,' that is, under general Imperial control. To these are added Ceylon, the Straits Settlements, and the Malay States, federated or other, North Borneo and Sarawak, and in the China Seas Hongkong and Wei-hai-wei. In South Africa we find Basutoland, Bechuanaland, and Rhodesia; in British West Africa, Gambia, the Gold Coast, Sierra Leone, and Nigeria; in Eastern and Central Africa, Somaliland, the East Africa Protectorate, Uganda, Zanzibar, and Nyassaland; while attached to Africa are the Mauritius, Seychelles, Ascension and St. Helena. In Central and South America are Honduras and British Guiana, and attached to that continent the Falkland Islands, and also Bermuda and the six colonies of British West Indies. In the Pacific Ocean are Fiji, Papua and many of the Pacific Islands.

I am afraid that once more during the course of this exposition I have been obliged to resort to a concentration of statement that is almost bewildering. But let that be. If one is to grapple successfully with a large and complex subject, it is necessary to try and keep before the mind, so far as possible, not only its magnitude, but the extent of its complexity. This is the reason for bringing before you, however briefly and generally, the main geographical

details of the British Empire. The first point to realise on such a survey is that the mere extent of such an Empire makes the subject of its administration an immensely important one for the British people.

The next point for consideration and realisation is that an empire situated in so many widely separated parts of the world must contain within its boundaries groups of every variety of mankind, in such numerical strength as to render it necessary to control them as individual entities. They do not consist of small bodies lost in a general population, and therefore negligible from the administrator's point of view, but of whole races and tribes or of large detachments thereof.

These tribes of mankind profess every variety of religion known. There are Christians, Jews, Mahommedans, Hindus, Buddhists, Jains, Animists, and to use a very modern expression, Animatists, adherents of main religions followed by an immense variety of sects, governed, however loosely, by every species of philosophy that is or has been in fashion among groups of mankind, and current in every stage of development, from the simplest and most primitive to the most historical and complex. One has to bear in mind that we have within our borders the Andamanese, the Papuan, and the Polynesian, as well as the highly civilised Hindu and Chinese, and that not one of these, nor indeed of many other peoples, has any tradition of philosophy or religion in common with our own; their very instincts of faith and belief following other lines than ours, the prejudices with which their minds are saturated being altogether alien to those with which we ourselves are deeply imbued.

The subjects of the British King-Emperor speak between them most of the languages of the world, and certainly every structural variety of human speech has its example somewhere in the British Empire. A number of these languages is still only in the process of becoming understood by our officials and other residents among their speakers, and let there be no mistake as to the magnitude of the question involved in the point of language alone in British Imperial regions. A man may be what is called a linguist. He may have a working knowledge of the main European languages and of the great Oriental tongues, Arabic, Persian, and Hindustani, which will carry him very far indeed among the people—in a sense, in fact, from London to Calcutta—and then, without leaving that compact portion of the British Possessions known as the Indian Empire, with all its immense variety of often incompatible subordinate languages and dialects, he has only to step across the border into Burma and the Further East to find himself in a totally different atmosphere of speech, where not one of the sounds, not one of the forms, not one of the methods, with which he has become familiarised is of any service to him whatever. The same observation will again be forced on him if he transfers himself thence to Southern Africa or to the Pacific Ocean. Let him wander amongst the North American Indians, and he will find the linguistic climate once more altogether changed.

Greater Britain may be said to exhibit all the many varieties of internal social relations that have been set up by tribes and groups of mankind—all the different forms of family and general social organisation, of reckoning kinship, of inheritance and control of the possession of property, of dealing with the birth of children and their education and training, physical, mental, moral, and professional, in many cases by methods entirely foreign to British ideas and habits. For instance, infanticide as a custom has many different sources of origin.

Our fellow subjects of the King follow, somewhere or other, all the different notions and habits that have been formed by mankind as to the relations between the sexes, both permanent and temporary, as to marriage and to what have been aptly termed supplementary unions. And finally, their methods of dealing with death and bringing it about, of disposing of the dead and worshipping them, give expression to ideas, which it requires study for an inhabitant of Great Britain to appreciate or understand. I may quote here as an example, that of all the forms of human head-hunting and other ceremonial murder that have come within my cognisance, either as an administrator or investigator, not one has originated in callousness or cruelty of character. Indeed, from the point of view of the perpetrators, they are invariably resorted to for

the temporal or spiritual benefit of themselves or their tribe. In making this remark, I must not be understood as proposing that they should not be put down, wherever that is practicable. I am merely trying now to give an anthropological explanation of human phenomena.

In very many parts of the British Empire, the routine of daily life and the notions that govern it often find no counterparts of any kind in those of the British Isles, in such matters as personal habits and etiquette on occasions of social intercourse. And yet, perhaps, nothing estranges the administrator from his people more than mistakes on these points. It is small matters—such as the mode of salutation, forms of address and politeness, as rules of precedence, hospitality, and decency, as recognition of superstitions, however apparently unreasonable—which largely govern social relations, which no stranger can afford to ignore, and which at the same time cannot be ascertained and observed correctly without due study.

The considerations so far urged to-day have carried us through the points of the nature and scope of the science of anthropology, the mental equipment necessary for the useful pursuit of it, the methods by which it can be successfully studied, the extent and nature of the British Empire, the kind of knowledge of the alien populations within its boundaries required by persons of British origin who would administer the Empire with benefit to the people dwelling in it, and the importance to such persons of acquiring that knowledge.

I now turn to the present situation as to this last point and its possible improvement, though in doing so I have to cover ground that some of those present may think I have already trodden bare. The main proposition here is simple enough. The Empire is governed from the British Isles, and therefore year by year a large number of young men is sent out to its various component parts, and to them must inevitably be entrusted in due course the administrative, commercial, and social control over many alien races. If their relations with the foreign peoples with whom they come in contact are to be successful, they must acquire a working knowledge of the habits, customs, and ideas that govern the conduct of those peoples, and of the conditions in which they pass their lives. All those who succeed find these things out for themselves, and discern that success in administration and commerce is intimately affected by success in social relations, and that that in its turn is dependent on the knowledge they may attain of those with whom they have to deal. They set about learning what they can, but of necessity empirically, trusting to keenness of observation, because such self-tuition is, as it were, a side issue in the immediate and imperative business of their lives. But, as I have already said elsewhere, the man who is obliged to obtain the requisite knowledge empirically, and without any previous training in observation, is heavily handicapped indeed in comparison with him who has already acquired the habit of right observation, and, what is of much more importance, has been put in the way of correctly interpreting his observations in his youth.

To put the proposition in its briefest form : in order to succeed in administration a man must use tact. Tact is the social expression of discernment and insight, qualities born of intuitive anthropological knowledge, and that is what it is necessary to induce in those sent abroad to become eventually the controllers of other kinds of men. What is required, therefore, is that in youth they should have imbibed the anthropological habit, so that as a result of having been taught how to study mankind, they may learn what it is necessary to know of those about them correctly, and in the shortest practicable time. The years of active life now unavoidably wasted in securing this knowledge, often inadequately and incorrectly even in the case of the ablest, can thus be saved, to the incalculable benefit of both the governors and the governed.

The situation has, for some years past, been appreciated by those who have occupied themselves with the science we are assembled here to promote, and several efforts have been made by the Royal Anthropological Institute and the Universities of Oxford, Cambridge, and London, at any rate to bring the public benefits accruing from the establishment of anthropological schools before the Government and the people of this country.

In 1902 the Royal Anthropological Institute sent a deputation to the Government with a view to the establishment of an official Anthropometric

Survey of the United Kingdom, in order to test the foundation for fears, then widely expressed, as to the physical deterioration of the population. In 1909 the Institute sent a second deputation to the present Government, to urge the need for the official training in anthropology of candidates for the Consular Service and of the Indian and Colonial Civil Services. There is happily every reason to hope that the Public Services Commission may act on the recommendations then made. This year (1913) the Institute returned to the charge and approached the Secretary of State for India, with a view to making anthropology an integral feature of the studies of the Oriental Research Institute, to the establishment of which the Government of India had officially proposed to give special attention. The Institute has also lately arranged to deal with all questions of scientific import that may come before the newly constituted Bureau of Ethnology at the Royal Colonial Institute, in the hope with its co-operation of eventually establishing a great *desideratum*—an Imperial Bureau of Ethnology. It has further had in hand a scheme for the systematic and thorough distribution of local correspondents throughout the world.

At Oxford, anthropology as a serious study was recognised by the appointment, in 1884, of a Reader, who was afterwards given the status of a Professor. In 1885, it was admitted as a special subject in the Final Honours School of Natural Science. In 1904, a memorandum was drawn up by those interested in the study at the University, advocating a method of systematic training in it, which resulted in the formation of the Committee of Anthropology in the following year. This Committee has established a series of lectures and examinations for a diploma, which can be taken as part of the degree course, but is open to all officers of the public services as well. By these means a School of Anthropology has been created at Oxford, which has already registered many students, among whom officers engaged in the administration of the British Colonies in Africa and members of the Indian Civil Service have been included. The whole question has been systematically taken up in all its aspects, the instruction, formal and informal, comprising physical anthropology, psychology, geographical distribution, prehistoric archæology, technology, sociology, and philology.

At Cambridge, in 1893, there was a recognised Lecturer in Physical Anthropology, an informal office now represented by a Lecturer in Physical Anthropology and a Reader in Ethnology, regularly appointed by the University. In 1904, as a result of an expedition to Torres Straits, a Board of Anthropological Studies was formed, and a Diploma in Anthropology instituted, to be granted, not for success in examinations, but in recognition of meritorious personal research. At the same time, in order to help students, among whom were included officials in the African and Indian Civil Services, the Board established lectures on the same subjects as those taught at Oxford. This year, 1913, the University has instituted an Anthropological Tripos for its Degrees on lines similar to the others. The distinguishing feature of the Cambridge system is the prominence given to field work, and this is attracting foreign students of all sorts.

In 1909, joint representations were made by a deputation from the Universities of Oxford and Cambridge to both the India and Colonial Offices, advocating the training of Civil Service candidates and probationers in ethnology and primitive religion.

In 1904, the generosity of a private individual established a Lectureship in Ethnology in connection with the University of London, which has since developed into a Professorship of Ethnology with a Lectureship in Physical Anthropology. In the same year the same benefactor instituted a Chair of Sociology. In 1909 the University established a Board of Anthropology, and the subject is now included in the curricula for the Degrees of the University. In and after 1914, Anthropology will be a branch of the Science Honours Degree. The Degree course of the future covers both physical and cultural anthropology in regard to zoology, palæontology, physiology, psychology, archæology, technology, sociology, linguistics and ethnology. There will also be courses in ethnology with special attention to field work for officials and missionaries, and it is interesting to note that students of Egyptology are already taking a course of lectures in ethnology and physical anthropology.

Though the Universities have thus been definite enough in their action where the authority is vested in them, it is needless to say that their representations to Governments have met with varying success, and so far they have not produced much practical result. But it is as well to note here that a precedent for the preliminary anthropological training of probationers in the Colonial Civil Service has been already set up, as the Government of the Sudan has directed that every candidate for its services shall go through a course of anthropology at Oxford or Cambridge. In addition to this, the Sudan Government has given a grant to enable a competent anthropologist from London to run a small scientific survey of the peoples under its administration. The Assam Government has arranged its ethnographical monographs on the lines of the British Association's 'Notes and Queries' with much benefit to itself, and it is believed that the Burma Government will do likewise.

Speaking in this place to such an audience as that before me, and encouraged by what has already been done elsewhere, I cannot think that I can be mistaken in venturing to recommend the encouragement of the study of anthropology to the University of such a city as Birmingham, which has almost unlimited interests throughout the British Empire. For it should be remembered that anthropological knowledge is as useful to merchants *in partibus* in dealing with aliens as to administrators so situated. Should this suggestion bear fruit, and should it be thought advisable some day to establish a School of Anthropology in Birmingham, I would also venture to point out that there are two requirements preliminary to the successful formation of almost any school of study. These are a library and a museum *ad hoc*. At Oxford there is a well known and well conducted anthropological museum in the Pitt-Rivers Collection, and the Museum of Archæology and Ethnology at Cambridge contains collections of the greatest service to the anthropologist. Liverpool is also interesting itself in such matters. The Royal Anthropological Institute is forming a special library, and both that Institute and the University of London have the benefit of the splendid collections of the British Museum and of the Horniman Museum readily accessible. The libraries at Oxford and Cambridge are, I need hardly say, of world-wide fame. At all these places of learning, then, these requisites for this department of knowledge are forthcoming.

It were almost superfluous to state why they are requisites. Every student requires, not only competent teachers to guide him in his particular branch of study, but also a library and a museum close at hand, where he can find the information he wants and the illustration of it. Where these exist, thither it will be found that students will flock. Birmingham possesses peculiar facilities for the formation of both, as the city has all over the Empire its commercial representatives, who can collect the required museum specimens on the spot. The financial labours also of those who distribute these men over Greater Britain, and indeed all over the world, produce the means to create the library and the school, and their universal interests provide the incentive for securing for those in their employ the best method of acquiring a knowledge of men that can be turned to useful commercial purpose. Beyond these suggestions I will not pursue this point now, except to express a hope that this discourse may lead to a discussion thereon before this meeting breaks up.

Before I quit my subject I would like to be somewhat insistent on the fact that, though I have been dwelling so far exclusively on the business side, as it were, of the study of anthropology, it has a personal side as well. I would like to impress once more on the student, as I have often had occasion to do already, that whether he is studying of his own free will or at the behest of circumstances, there is hardly any better hobby in existence than this, or one that can be ridden with greater pleasure. It cannot, of course, be mastered in a day. At first the lessons will be a grind. Then, until they are well learnt, they are irksome, but when fullness of knowledge and maturity of judgment are attained, there is, perhaps, no keener sense of satisfaction which human beings can experience than that which is afforded by this study. Its range is so wide, its phases so very many, the interests involved in it so various, that it cannot fail to pleasantly occupy the leisure hours from youth to full manhood, and to be a solace, in some aspect or other, in advanced life and old age.

The processes of discovery in the course of this study are of such interest

in themselves that I should wish to give many instances, but I must confine myself now to one or two. The student will find on investigation, for instance, that however childish the reasoning of savages may appear to be on abstract subjects, and however silly some of their customs may seem, they are neither childish nor silly in reality. They are almost always the result of 'correct argument from a false premiss'—a mental process not unknown to civilised races. The student will also surely find that savages are not fools where their concrete interests are concerned, as they conceive those interests to be. For example, in commerce, beads do not appeal to savages merely because they are pretty things, except for purposes of adornment. They will only part with articles they value for particular sorts of beads which are to them money, in that they can procure in exchange for them, in their own country, something they much desire. They have no other reason for accepting any kind of bead in payment for goods. On few anthropological points can mistakes be made more readily than on this, and when they are made by merchants, financial disaster can well follow, so that what I have already said elsewhere as to this may bear repetition in part here. Savages in their bargains with civilised man never make one that does not, for reasons of their own, satisfy themselves. Each side, in such a case, views the bargain according to its own interest. On his side, the trader buys something of great value to him, when he has taken it elsewhere, with something of little value to him, which he has brought from elsewhere, and then, and only then, can he make what is to him a magnificent bargain. On the other hand the savage is more than satisfied, because with what he has got from the trader he can procure from among his own people something he very much covets, which the article he parted with could not have procured for him. Both sides profit by the bargain from their respective points of view, and traders cannot, as a matter of fact, take undue advantage of savages, who, as a body, part with products of little or no value to themselves for others of vital importance, though these last may be of little or none to the civilised trader The more one dives into recorded bargains, the more clearly one sees the truth of this view.

I have always advocated personal inquiry into the native currency and money, even of pre-British days, of the people amongst whom a Britisher's lot is cast, for the reason that the study of the mental processes that lead up to commercial relations, internal and external, the customs concerned with daily buying and selling, take one more deeply into aliens' habits of mind and their outlook on practical life than any other branch of research. The student will find himself involuntarily acquiring a knowledge of the whole life of a people, even of superstitions and local politics, matters that commercial men, as well as administrators, cannot, if they only knew it, ever afford to ignore. The study has also a great intellectual interest, and neither the man of commerce nor the man of affairs should disregard this side of it if he would attain success in every sense of that term.

Just let me give one instance from personal experience. A few years back a number of ingots of tin, in the form of birds and animals and imitations thereof, hollow tokens of tin ingots, together with a number of rough notes taken on the spot, were handed over to me for investigation and report. They came from the Federated Malay States, and were variously said to have been used as toys and as money in some form. A long and careful investigation unearthed the whole story They turned out to be surviving specimens of an obsolete and forgotten Malay currency. Bit by bit, by researches into travellers' stories and old records, European and vernacular, it was ascertained that some of the specimens were currency and some money, and that they belonged to two separate series. Their relations to each other were ascertained, and also to the currencies of the European and Oriental nations with whom the Malays of the Peninsula had come in contact. The mint profit in some instances, and in other instances the actual profit European governments and mercantile authorities, and even native traders, had made in recorded transactions of the past, was found out. The origin of the British, Dutch, and Portuguese money, evolved for trading with the Malays, was disclosed, and several interesting historical discoveries were made; as, for instance, the explanation of the coins still remaining in museums and issued in 1510 by the

great Portuguese conqueror, Albuquerque, for the then new Malay possessions of his country, and the meaning of the numismatic plates of the great French traveller Tavernier in the next century. Perhaps the most interesting, and anthropologically the most important, discovery was the relation of the ideas that led up to the animal currency of the Malays to similar ideas in India, Central Asia, China, and Europe itself throughout all historical times. One wonders how many people in these isles grasp the fact that our own monetary scale of 960 farthings to the sovereign, and the native Malay scale of 1,280 cash to the dollar, are representatives of one and the same universal scale, with more than probably one and the same origin out of a simple method of counting seeds, peas, beans, shells, or other small natural constant weights. But the point for the present purpose is that not only will the student find that long practice in anthropological inquiry, and the learning resulting therefrom, will enable him to make similar discoveries, but also that the process of discovery is intensely interesting. Such discoveries, too, are of practical value. In this instance they have taught us much of native habits of thought and views of life in newly acquired possessions which no administrator there, mercantile or governmental, can set aside with safety.

I must not dwell too long on this aspect of my subject, and will only add the following remark. If any of my hearers will go to the Pitt-Rivers Museum at Oxford he will find many small collections recording the historical evolution of various common objects. Among them is a series showing the history of the tobacco pipe, commonly known to literary students in this country as the nargileh and to Orientalists as the hukka. At one end of the series will be found a hollow coconut with an artificial hole in it, and then every step in evolution between that and an elaborate hukka with its long, flexible, drawing-tube at the other end. I give this instance as I contributed the series, and I well remember the eagerness of the hunt in the Indian bazaars and the satisfaction on proving every step in the evolution.

There is one aspect of life where the anthropological instinct would be more than useful, but to which, alas, it cannot be extended in practice. Politics, government, and administration are so interdependent throughout the world that it has always seemed to me to be a pity that the value to himself of following the principles of anthropology cannot be impressed on the average politician of any nationality. I fear it is hopeless to expect it. Were it only possible the extent of the consequent benefit to mankind is at present beyond human forecast, as then the politician could approach his work without that arrogance of ignorance of his fellow countrymen on all points except their credulity that is the bane of the ordinary types of his kind wherever found, with which they have always poisoned and are still poisoning their minds, mistaking the satisfaction of the immediate temporary interests and prejudices of themselves and comrades for the permanent advantage of the whole people, whom, in consequence, they incontinently misgovern whenever and for so long as their country is so undiscerning as to place them in power.

Permit me, in conclusion, to enforce the main argument of this address by a personal note. It was my fortune to have been partly trained in youth at a University College, where the tendency was to produce men of affairs rather than men of the schools, and only the other day it was my privilege to hear the present master of the College, my own contemporary and fellow-undergraduate, expound the system of training still carried out there. 'In the government of young men,' he said, 'intellect is all very well, but sympathy counts for very much more.' Here we have the root principle of Applied Anthropology. Here we have in a nutshell the full import of its teaching. The sound administration of the affairs of men can only be based on cultured sympathy, that sympathy on sure knowledge, that knowledge on competent study, that study on accurate inquiry, that inquiry on right method, and that method on continuous experience.

A Joint Discussion with Section L on the Educational Use of Museums followed.—See p. 743.

The following Papers were then read :—

1. *On the Relative Age of the Tribes with Patrilineal and Matrilineal Descent in South-East Australia.* By Prof. W. J. SOLLAS, *F.R.S.*

If, as appears probable, Tasmania was peopled by immigration from Australia, and Australia by immigration from New Guinea, we should expect to find traces of the more primitive people, if they survive anywhere, in the south rather than in the north of the continent. An examination of the available evidence seems to show that this expectation is satisfied by the facts. In material culture there is not much which is distinctive of the south, yet it is important to note that the canoes of the south-east are made in a more primitive manner than those in the north, the bark of which they are formed being merely bent into shape and not sawn; in the south-west canoes are unknown, rafts taking their place. On the intellectual and religious side greater differences are manifest. Totemism, which flourishes so luxuriantly over the rest of Australia, falls almost into abeyance in the extreme south, and though this may be partly explained by disuse, yet there is nothing to show that totemism had ever attained so great a hold upon the people of Victoria and the adjacent part of South Australia as it has elsewhere.[1]

The distribution of the rite of circumcision throws very little light on this question; it is limited to a wide median band which extends from the northern to the southern coast; it seems to have invaded the country from the north, and to have spread by a kind of missionary propaganda.

Among the Kurnai of Gippsland the initiatory ceremonies are simpler than elsewhere, and the knocking out of teeth forms no part of them. In contrast to the Dieri, these people have no gesture language, and their message sticks are the most primitive yet met with.

More important evidence, however, is afforded by language, and Father Schmidt has shown that the language of the Kurnai and the other languages of Victoria allied to it show a closer approach to Tasmanian than is made by any other Australian tongue.

Equally strong evidence in the same direction may be obtained from a study of bodily characters. Platycephaly, a character generally regarded as primitive, increases as we proceed from north to south; thus, in Queensland only 3 per cent. of the skulls examined are platycephalic; in New South Wales, 33 per cent.; in Victoria, 46 per cent.; and in the south of South Australia, no less than 76 per cent.; in Tasmania the proportion is 75 per cent.

Howitt remarks that 'in a district like Gippsland, cut off by . . . physical features . . . from facile intercourse with the remainder of Australia, we should naturally expect to find the social condition of the people "old fashioned,"' and then proceeds to assert that this is by no means the case; basing this statement on the absence of the class system and the existence, not of matrilineal, but patrilineal descent. This, of course, involves the assumption that the class system and matrilineal descent are the more primitive. As a universal rule I do not think this will hold, nor do I think it holds for the Kurnai. The primitive character of this people is established by a considerable body of evidence, which is, on the whole, of a more positive character than that which is afforded by their social organisation. Among the East Kulin people, also characterised by patrilineal descent and local exogamy, we have, further, a local separation into Eagle-hawks and Crows, distinguished by different dialects and different bodily characters—a fact suggestive of the origin of the class system in the alliance of different races. It would seem that the Arunta are among the least primitive of the Australian races.

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[1] In Tasmania the only evidence for the existence of totemism rests on the statement that some natives would eat only the male wallaby, others only the female.

2. *The Historical Value of the Traditions of the Baganda.* *By* E. Sidney Hartland.

The recent tendency among ethnological inquirers to accept the oral traditions of peoples in the lower culture at their face value as historical evidence is contrary to true critical principles. The influence of imagination in reconstituting the past, the measures taken by various African peoples to preserve the memory of past events, and the special dangers attendant on such measures. The length of time to which genuine historical memory extends may be illustrated by the pedigrees of the Thonga chiefs. A summary examination of the traditions of the Baganda as recorded by the Rev. J. Roscoe and Sir Harry Johnston. Their historical value has been greatly over estimated.

3. *A Gypsy Pedigree and its Lessons.* *By* Rev. George Hall *and* W. H. R. Rivers, *M.D., F.R.S.*

The pedigree of a well-known family, extending over six generations, has been analysed with the object of ascertaining how far the collection of gypsy pedigrees is likely to furnish data of sociological and biological interest.

One result has been to show a great increase in the proportion of marriages outside the gypsy community in the later as compared with the earlier generations of the family. The pedigree also shows a large proportion of marriages between relatives. In the earlier generations there is one case of marriage with a half-sister, and two between uncle and niece. Marriages between cousins of various kinds occur throughout, but less frequently in proportion to the total number in the later generations. In the cases of the marriage of first cousins the children of two brothers have married more frequently than the children of brother and sister or of two sisters.

Several cases of polygamy are recorded, and an examination of the marriages of widows and widowers show no trace of the Levirate, and only one case of marriage with the deceased wife's sister.

The chief points of biological interest to be learnt from the pedigree are that there is no evidence of any diminution in the size of the family, and that, as among other peoples, there is an excess of male births, while the first-born child is more often male than female. There is also evidence that the consanguineous marriages have been as fertile as those between persons unrelated to one another.

The analysis is only intended as an example of the method by which the social and biological characters of the gypsies may be studied when more of their pedigrees have been recorded.

4. *Gypsy Taboos and Funeral Rites.* *By* T. W. Thompson, *M.A.*

This paper, which contained a selection from a large mass of material, collected from all available sources, dealt especially with the British gypsies, with some two or three thousand of whom the author is personally acquainted, and with the German gypsies, who are more closely akin to our own than any other, whose taboos and funeral rites have just been completely revealed to us in the writings of one of their number, Englebert Wittich, and of whom the author has some first-hand knowledge.

A woman's dress must not be allowed to touch any article of food, or any vessel in which food is prepared or from which it is eaten, otherwise the food or vessel in question becomes *mokhadi* (ceremonially contaminated), and must be destroyed. There are many other similar prohibitions based on the belief that the same contaminating influence emanates from anything used in the washing of apparel or of the person, and anything connected with the toilet or with the bed; also from any sick person. These prohibitions are multiplied and intensified on the occasion of child-birth.

But it is not only dirt and disease that cling to and are conveyed in clothing; amongst other things may be mentioned spells and bad luck. This seems to throw some light on the custom of burning, or otherwise destroying, the effects

of a dead person, which is the main feature of gypsy funeral rites. The destruction, it would appear, is carried out, not to benefit the deceased in his future life, but from fear that his belongings should afford a lurking ground for his ghost. This reason is sometimes alleged by the gypsies themselves. It is fear of his ghost that doubtless underlies such taboos as the prohibition on the use of the name of the dead person, and on the indulgence in his favourite food or drink or form of amusement. In all probability it also accounts for the now extinct customs of burying the body in an isolated place or in a ditch, and of planting thorns over the grave. There are several other interesting funeral rites, but they have a more restricted currency.

Dread of contamination is perhaps responsible for the fact that offences against chastity, which very rarely occur, used, until quite recently, to be punished by death, or by branding and expulsion from the band; and there is some slight evidence to prove that this same dread underlies their one-time aversion from marriage in churches.

Variety and instability are the characteristics of their marriage rites, and this contrasts markedly with the unity and persistence of their funeral rites. It suggests that they originally had none at all, but acquired such as they have practised from time to time by borrowing from European peoples, just as, since their arrival in England, they have picked up (and possibly helped to disseminate) some of our native tunes, songs, and dances, medical recipes, charms and omens. Parallels to most of their marriage rites can be found in European folk-lore. Not so their taboos and funeral rites, for, whatever their origin, it is quite safe to say that the gypsies brought them with them into Western Europe. They are intensely, typically, but not exclusively, gypsy.

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5. *Social Organisation amongst the Primitive Tribes of Northern Nigeria.* *By* Mrs. Charles Temple.

The President's remarks in his opening address emphasise the use of the study of native customs (applied ethnology) in administration. This study has received particular attention from the Government in Northern Nigeria, where, in certain cases, native customs have been perpetuated by embodiment in local statutes. It is proposed, however, to confine this paper to a review of the customs of those tribes which, to differentiate them from Moslems and Christians, are commonly called Pagan—a somewhat misleading title, as in most cases their religion comprises a belief in an all-powerful God, as well as in animism and ancestor worship.

Divided into two parts, the first section of the paper describes generally the principal native institutions, and the second part supplements the first by concrete examples.

The basic principle of all the institutions of these tribes was to place the interests of the community first and those of the individual second, as must be the case with peoples whose right to exist has been challenged for generations by their neighbours, and amongst whom lack of cohesion meant extinction.

The system of land tenure has the first place of importance. Rude necessity compelled them to realise that it was essential that each individual should have the right to occupy sufficient land for his needs and for that of his family, and that, as a corollary, it was harmful to the community that land should be monopolised by an individual, or group of individuals.

Unoccupied lands also are jealously claimed and protected, and cannot even be temporarily alienated without the consent of the community. Land cannot be bought, sold, or mortgaged, for the living individual has a right of occupancy only—a right which, however, passes to his heirs so long as he and they make use of the land and observe the tribal laws. Thus land, the first necessity of life, is preserved for the use of the community for all time, the usufruct only going to the individual.

The entire machinery of government is directed towards the preservation of the tribe as a whole. Every able-bodied male is expected to turn out for common defence, much importance being attached to physical fitness; there is, however, no purely military caste amongst the tribes of Northern Nigeria. This same

principle applies to domestic organisation also. Thus a man with his wife and children does not live to himself for his own aggrandisement or theirs, but as a unit of a larger family, owing allegiance to the senior, or patriarch, who is, as a rule, the oldest male member of a generation, granting his physical fitness for the post, which bears with it clearly defined and often onerous duties. There is, however, no 'socialism' or 'collectivism,' in that the rights of the individual to the fruits of his personal labour are strictly respected by other members of his tribe. Besides blood-relations the family consists of dependants and slaves, who all owe allegiance to the Family Head. In many tribes these patriarchs formed a Council of Elders and together directed the affairs of the community, under the chairmanship of one of their number, who, in this limited sense, became Village-Chief. Those tribes, however, who had united for purposes of defence and expansion, recognised one Tribal Chief who was supreme over all, and he would often appoint sub-chiefs with jurisdiction over certain clearly defined areas.

Whichever form of constitution is adopted, the executive and judicial functions of Government are not separated. Sometimes the Chiefs also performed the duties of High Priest; sometimes, however, others were appointed to this office, and it occasionally occurred that they snatched the power of the Chiefs and reduced them to servility; but in a firmly established and prosperous tribe we never find the two authorities in conflict. Punishment for crimes inflicted by the communal authority very generally takes the form of compelling the criminal to compensate the injured party, though amongst certain communities habitual malefactors are sold out of or banished from their tribe. In cases where guilt or innocence is believed to exist but is hard to prove, the judicial executive shelter themselves behind ordeal, when, to take a common instance, the accused is invited to establish his innocence by drinking water poisoned with sasswood, the Elders having already decided the effect it is to have. Death by ordeal is therefore a mode of execution like any other.

This is a good example of a perfectly reasonable custom, which, however, at the first glance appears senseless and barbarous to our ideas.

The second section of the paper gave examples illustrating the customs outlined above, which can only be briefly epitomised here.

Ingara tribe : history available since fifteenth century : origin and development : administrative organisation : succession of Chief : taxation : land system : mode of administering justice by family heads, travelling judges, chief justice, with appeal to Chief.

Gamawa tribe : mode of administering justice.

Batta tribe : alternative succession to Chiefdom : sub chiefs : taxation : land system : settlement of disputes by family heads : punishments : ordeals.

Verre tribe : office of Chief and High Priest combined : ordeals, by poison and hunting dangerous game.

Mumye tribe : no distinct Chief : government by family heads, physical fitness essential. Aggrieved parties permitted to extract compensation from aggressor on fixed scale.

Angass tribe : cannibalism : Chief elected by council of four elders : functions of Chief, administrative and religious.

Jukum tribe : historical note from eleventh century : Chieftainship, absolute power coupled with brief tenure.

Munshi tribe : organisation, conglomeration of families : signalling : sasswood ordeal, mode of discriminating by Chief.

Bassa tribe : intermixture with other tribes : emigrations : land system : administration of justice : ordeal : punishments : domestic slavery.

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6. *Some Notes on Hausa Magic.*
By Major A. J. N. Tremearne, *M.A.*

The Hausa resorts to magic not only for success in love, in agriculture, in hunting, and in war, but also to part married couples, to destroy a rival's property, and to promote trade. The charms are prepared by mallams (Mohammedan priests) or bokas (medicine men), while the more important members of

the bori (spirit) sect may divine and prescribe remedies for illnesses. Charms are sought even from Europeans.

Love-charms consist of decoctions which must be eaten by the person desired, and there is usually some spittle of the amorous swain contained in them. Wives can deceive their husbands with complacence by using the earth from a grave, or better still, the hand of a corpse, for these produce a soporific effect. The evil-eye and the evil-mouth are greatly feared, so many charms and amulets are used against them, the most common being the hand or 'five' (fingers). If a shred of the clothing or some other article intimately connected with the evil wisher can be obtained the influence can be neutralised. The remains of a dog's food are a very powerful charm.

The Mohammedan Hausas (and Arabs) worship Allah so long as all goes well, but if he fails them they have recourse to the magic of the pagans. In Tunis if the Arab prayers fail to have any effect upon a drought, the Hausas go in procession to a shrine on a hill near the city, and there offer a sacrifice, summon the bori, and perform the *takai* dance. While the sacrificial animal is being roasted pieces of the meat are stolen by some of the youths, others pursuing them, this being supposed to drive away evil influences. There are also charms for preventing rain.

Agriculture plays an important part in the life of the people in their own country. Sacrifices are offered to Uwar-Gwona (Farm-Mother) when the corn begins to appear, and she increases the crops of her worshippers. Magiro is another corn-spirit, but he demands a human victim.

Hunters and warriors can make talismans which confer invisibility, and if a young girl with her first teeth helps, the wearer will be protected against all; but boys with their first teeth can wound persons protected only by ordinary charms. The kind of death struggles of a victim can be determined by sympathetic actions during the preparation of the poison.

Wrestling was once a religious rite. By a proper initiation and by regular sacrifices a youth could become invincible, for whenever he wrestled a red cock would appear upon his head, a white hen at his feet, and the sight of these would render his opponents powerless.

FRIDAY, SEPTEMBER 12.

The following Papers were read :—

1. *Recent Archæological Discoveries in the Channel Islands.*[1] *By* R. R. Marett, *M.A.*, *D.Sc.*

1. The cave known as La Cotte de St. Brelade, on the south coast of Jersey, was excavated—to the extent of about one-third—by the Société Jersiaise in 1910 and 1911, and provided a rich spoil of relics, including human remains, belonging to the Mousterian Period (see *Rep. Brit. Assoc.*, 1911, 1912). As members of the British Association party will remember who visited the site after the Portsmouth meeting, this cave occurs at the north-east corner of a deep ravine in the granite cliff, the sides of the ravine rising vertically some 40 feet apart, while the wall to the rear is masked by a steep and heavy talus. In August and September 1912 the proprietor, Mr. G. F. B. de Gruchy, and the present writer carried on excavations beneath the talus at the south-east corner, and were successful in unearthing the entrance of a second cave—or, possibly, of a cave running right round the back of the ravine, and hence continuous with La Cotte. Here, after some 250 tons of rock-rubbish had been removed, a Mousterian floor with characteristic implements was reached at a depth of 27 feet. There seemed good prospect of finding bone in decent condition, as the soil was dry—far drier than that of La Cotte. Unfortunately at this point operations were cut short by the dangerous state of the overhanging talus, no funds being available for its systematic demolition. An application will be made to the British Association

[1] To be published in *Archæologia.*

for a grant to carry to a finish an investigation that has already contributed something to the advancement of science. It is estimated that 100*l.* would nearly suffice for the complete excavation of La Cotte, while the uncovering of the whole back of the ravine might cost another 100*l.*, or perhaps rather more. It would be advisable to attack La Cotte first, as it is more certain to yield solid results, and, indeed, can hardly fail to prove a gold-mine.

2. Exploration of a dolmen, containing interments, pottery, &c., at Les Monts Grantez, at St. Ouen's, Jersey, in September 1912.

3. Discovery and examination of a cist or dolmen of a type novel to the island, with surrounding stone circles and graves, at L'Islet, St. Sampson's, Guernsey, in October and November 1912.

4. Other recent finds, ranging from alleged eoliths (Jersey) and palæoliths (Guernsey) to a stone object resembling a mould, found in the Lower Peat—*i.e.*, at the neolithic level—but more probably belonging to a later period (Jersey).

2. *Flint Implements found in the County of Hampshire. By* W. DALE, *F.S.A.*

A series of flint implements was exhibited of the kind usually called 'celts,' all from the county of Hants. Being found in the surface soil, or never at a greater depth than two feet, these would have been called a few years back Neolithic. Some leading archæologists, however, have lately made a special study of the forms of the implements abroad belonging to the later ages of the Palæolithic period and have compared with them implements found on well-known British sites, such as Grimes's Graves and Cissbury, with the result that they consider many of the chipped celts found at the places named and elsewhere should be considered late Palæolithic rather than Neolithic. They also maintain that the great gap or 'hiatus' which was supposed to separate the Palæolithic from the Neolithic age does not exist, but that the ages were continuous. Also it is advanced by some that the art of rubbing or polishing stone was also known in late Palæolithic times.

It was in illustration of these views that this series was shown. It contained a number of both carefully chipped and rough celts, many of the well-known Cissbury type. Celts of Cissbury form slightly rubbed were also shown, and the series ended with specimens of the perfectly polished celts. Some of the celts are covered with iron stains, which abroad is taken as a proof of antiquity.

3. *Excavations on the Site of the Roman Town of Viroconium at Wroxeter, Salop.*[1] *By* J. P. BUSHE-FOX.

These excavations, undertaken by the Society of Antiquaries in conjunction with the Shropshire Archæological Society, are now in their second season.

The ancient name of the town was Uriconium or Viroconium. The area within the walls amounted to about 170 acres—about one-third larger than Silchester. It is situated some six miles south-east of Shrewsbury.

The site appears to have been inhabited from the earliest days of the Roman conquest. Its first occupation must have been a military one, as tombstones of soldiers of the Fourteenth Legion have been found in the cemetery. This legion left Britain for good in the year A.D. 70. The site, lying as it does on the east side of the Severn, and thus protected from the mountainous district on the west, would have formed an admirable base against the turbulent tribes of Wales, which gave the Romans so much trouble in the first century of our era.

After the cessation of hostilities, the town, situated at the junction of two of the main Roman roads, appears to have grown into one of the largest Romano-British centres. Although there were larger towns in Britain, Wroxeter is the largest which can be almost entirely excavated, as it lies in the open country, without any large modern town built over it.

During 1912 about two acres were excavated near the centre of the town, and revealed four large houses facing on to a street. This street appeared to be one of the main roads of the town, and a direct continuation of the Watling Street,

[1] To be published in *Archæologia*.

which entered the town on the north-east. Another Roman road, running from Caerleon in South Wales, and passing through Kenchester and Church Stretton, entered the town on the south-west.

Although all the buildings found differed considerably, yet their general arrangement was similar. They appeared to have been large shops, with dwelling rooms at the back, and wooden or stone verandas or porticoes in front, under which ran a continuous pathway parallel to the street. The buildings had undergone many alterations during the period of the Roman occupation, which lasted for upwards of 350 years. One house showed as many as five distinct constructions, which had been superimposed one on the other. In connection with the houses were five wells, all of them stone-lined, and with an average depth of about 12 feet. One well was complete, with coping stones and stone trough, and appeared as it did when in use in Roman times.

A large number of small objects were found; they included engraved gems from rings, brooches of different metals—one set with stones and others enamelled—portions of two small statuettes of Venus and one of Juno Lucina; also a small pewter statuette of Victory. One of the most interesting was a pewter circular bronze disc with a device, in different coloured enamels, of an eagle holding a fish. Nothing similar to it of the Roman period in Britain appears to have been found before.

Pottery of every description came to light. There were specimens from most of the principal Roman potteries on the Continent, much decorated Samian ware (*Terra sigillata*), and over 300 pieces bearing potters' names. The coins numbered between 200 and 300, and ranged from Claudius to Gratian (A.D. 41 to A.D. 383).

This year a temple has been uncovered. It consisted of a podium measuring 25 feet by 31 feet, the walls of which were formed of large blocks of red sandstone. The space within these walls was packed with stones and clay to form a support for the raised *cella* above. Enclosing walls surrounded the podium, having a space or ambulatory at the back and sides and a spacious courtyard in front. The entrance into the latter was from the main street under a portico of six columns. The whole structure measured 94 feet deep by 55 feet wide.

Many carved architectural fragments, portions of several statues, and the head of a horse were discovered in clearing the site. The top of a well-finished altar was also found, but unfortunately the part bearing the inscription was missing, and there is no evidence to show to whom the temple was dedicated.

Areas to the north and west of the temple buildings are now being excavated. Three hypocausts, several rooms with *opus signinum* floors, and one with a rough mosaic pavement have already been uncovered. One well containing first-century pottery has been cleared out.

The small finds are numerous and interesting, and there is a large amount of pottery. About 120 potters' stamps on Samian ware have already been recorded.

The coins number over 200, and date from the Republican period to Theodosius I.

4. *Discussion on the Practical Application of Anthropoligical Teaching in Universities, in which* Sir RICHARD C. TEMPLE, *Bart.*, *C.I.E.*, Sir E. F. IM THURN, *K.C.M.G.*, Lieut.-Col. P. R. GURDON, Dr. A. C. HADDON, Dr. R. R. MARETT, *and* Prof. P. THOMPSON *took part.*[1]

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5. *The Via Appia. By* T. ASHBY, *M.A.*, *D.Litt.*

The Via Appia, the queen of Roman roads, as Statius calls it, played a very important part in the advance of the Roman power into South Italy, for the Romans thoroughly understood the military necessity of good communication with their base. Constructed originally by the censor Appius Claudius Cæcus as far as Capua in 312 B.C., it was prolonged successively to Beneventum, Venusia (where a colony of 20,000 men was placed to hold the territory already won), Tarentum, and Brundusium (Brindisi), which it probably reached in 245 B.C., the date of

[1] Published in full in *Man*, 1913, No. 102.

the foundation of the Roman colony there. After the Punic wars it became the chief route to the East, Brundusium being the usual port of embarkation. As far as Beneventum its course is certain, and considerable remains of it exist; but beyond this town there is considerable doubt about its course, and a careful examination on the spot of the possible routes was not sufficient to give certainty. From a point shortly before Venusia its line is once more fairly clear, but almost all traces of it have been obliterated by one of the great sheep tracks, known as *tratturi*, which traverse this portion of Italy. There is also considerable doubt about the route taken by Horace between Beneventum and Canusium; beyond the latter town, if not before, it coincided with the later Via Traiana, constructed by the emperor whose name it bears. There are hardly any traces of it left, however, except in the mountainous region between Beneventum and Aecæ (mod. Troia), and in the valleys of two rivers south of Foggia, where considerable remains of its bridges exist.

In the neighbourhood of Bari, in the territory traversed by the Via Traiana, are the only dolmens and menhirs to be found in Italy, except the group in the Terra d'Otranto, the extremity of the heel, and a somewhat unexpected discovery was that of a group of four hitherto unknown menhirs close to the road.

6. *The Aqueducts of Ancient Rome.* *By* T. Ashby, *M.A.*, *D.Litt.*

The principal supplies of water for ancient Rome were derived from the upper valley of the Anio. The second of the aqueducts in point of date, constructed in 272–269 B.C., drew its water and its name (Anio Vetus, the old Anio) from the river itself; while the third, the Aqua Marcia, built in 144–140 B.C., made use of some very considerable springs on the right bank of the river, which gushed forth from beneath the limestone rock. During the following century use was made of various springs in the more immediate neighbourhood of the city, of which the Aqua Virgo was the most important; but Caligula's engineers returned to the Anio Valley, and the Aqua Claudia and Anio Novus, both completed by Claudius in A.D. 52, drew their water respectively from the springs which the Marcia had already tapped, and from the river. The remains of these four aqueducts are very considerable, and comparatively little known; and by careful research on the spot it has been possible to determine their course with fair accuracy from the springs to the city, even in the portion where they ran underground through the lower slopes of the Alban Hills: for here their presence is betrayed by the remains of the shafts which were used for ventilation and for cleaning, and by the fragments of calcareous deposit which were removed from their channels. Inasmuch, however, as they travel close together it would be very desirable that the remains should be accurately levelled; a certain amount of excavation would be necessary, and the enterprise may, it is to be hoped, one day be undertaken by the Italian authorities.

7. *Excavations at the Hill Fort in Parc-y-Meirch Wood, Kinmel Park, Abergele.* *By* Willoughby Gardner.—See Report on Excavations on Roman Sites in Britain, p. 231.

MONDAY, SEPTEMBER 15.

The following Papers were read:—

1. *The Orientation of the Dead in Indonesia.*[1] *By* W. J. Perry, *B.A.*

The table which is printed below shows at once the aim of the practice of orientation. It will be seen that in all the cases quoted—which are all that

[1] To be published in *Journ. R. Anthrop. Inst.*

I have as yet been able to collect—the dead are made to face in the direction of the Land of the Dead. This Land of the Dead is again in the direction of the land from which the folk in question believe themselves to have come.

—	Direction of Orientation	Direction of Land of Dead	Direction of Home of Forefathers
Kachari	S.	Not known	S. or E.
Khasi	E.	Not known	E.
Kuki-Kom	S.	S.	S.
Karo-Batak	W.	W.	Not known
Badoej	S.	S.	S.
Tenggerese	Orientation towards holy mountain		
Mantra	W.E.	Not known	W.
Olo Ngadjoe	Orient towards the land of the dead		
To-Radja	W.	W.	Not known
Halmahera	W.	E.W.	W.
Kei	N.	N.	N.
Timorlaut	W.E.	W.	W.
Babar	W.	W.	W.
Leti, Moa, Lakor	E.	E.	E.
Tettum	Orient towards the land of the dead		
S. W. Timor	E.	Not known	E.
Savoe	W.	W.	W.

2. *The Stability of Tribal and Caste Groups in India.*[1] *By* W. Crooke, *B.A.*

In this paper the following statement by the late Sir H. Risley was discussed: That 'nowhere else in the world do we find the population of a large continent broken up into an infinite number of mutually exclusive aggregates, the members of which are forbidden by an inexorable social law to marry outside of the group to which they themselves belong. . . . In this respect India presents a contrast to most other parts of the world, where anthropometry has to confess itself hindered, if not baffled, by the inter-mixture of types obscuring and confusing the data ascertained by measurements.'

In opposition to this doctrine, an attempt was made to show that, in spite of the formal rules regulating endogamy and exogamy, there is much less stability in the tribal and caste groups than Risley supposed to exist. In particular, many of the larger groups were shown to be distinctly heterogeneous; the tendencies promoting miscegenation were discussed; and the effect of these conclusions on the validity of the anthropometric evidence considered.

3. *Souling, Clementing, and Catterning: Three November Customs of the Western Midlands.*[2] *By* Miss C. S. Burne.

Early calendar festivals were at once religious, social, and economic. The Celtic and, maybe, the Teutonic year also, began and ended in November. It was a season of social enjoyment and also a Feast of the Dead. The 1st of November, 'Hallowmas,' or the Feast of All Saints (followed by that of All Souls), besides being a high ecclesiastical festival and the occasion of special ceremonies and amusements, is still in some parts of Great Britain the date for entering on and terminating annual tenancies and business contracts. In Cheshire, North Shropshire, and North Staffordshire, children observe it by begging for cakes, ale, and apples. This they call 'Souling.' But in South Staffordshire the dole of ale and apples is solicited on St. Clement's Day,

[1] To be published in *Journ. R. Anthrop. Inst.* or *Man.*
[2] To be published in *Folklore.*

November 23: in North Worcestershire on St. Katharine's, November 25. The name varies accordingly. The areas of 'Clementing' and 'Catterning' seem to be determined by the customs of the local trades and the cults of patron saints. The dole probably belongs to the economic side of the festival, and was a sequel to the annual settlement of accounts.

The observances as practised to-day show traces of early agricultural custom, of successive importations of foreign culture, and of the growth and decay of early economic institutions.

4. *Evidence for the Custom of Killing the King in Ancient Egypt.*[1] *By* Miss M. A. Murray.

Dr. Frazer deduced the general practice of killing the King from literary sources, from legend, and from ceremonial survivals; a theory not at first received by all, but triumphantly confirmed in the end by Dr. Seligmann's discoveries among the Shilluks of the Nile Valley. In the same way we follow 'the converging lines of evidence' in ancient Egypt.

The evidence for human sacrifice in ancient Egypt is conclusive, in spite of what Herodotus says. As regards the cult of Osiris, with which this paper mainly dealt, the theory of the vegetation spirit (the theory so despised by Plutarch) is the only one which so far covers all the facts in Egypt, as Dr. Frazer has shown it to cover the facts in other countries.

The subject is divisible into five parts: (1) the parallels in neighbouring countries; (2) the meaning of the name Osiris (the identification of the King with Osiris being already established); (3) the literary evidence—from the Pyramid Texts, from the Book of the Dead, and from legends both Egyptian and Arab; (4) the representations in Art, *i.e.*, the Sed-festival and the Drowned Men of Dendur; (5) the modern survivals. A summary of the work which has been done bearing on this subject by Frazer, Sethe, Möller, Petrie, Seligmann, and Moret showed what was old and what was new in this paper, and made it possible to offer a few suggestions as to the lines on which further research might be pursued.

5. *Hook-swinging in India.*[2] *By* J. H. Powell.

Hook-swinging, a rite in which the devotee is suspended by means of hooks passed through his back, has in certain parts of India been more or less common, but is now disappearing.

The ceremony is still practised in certain villages of Chota Nagpur. Two hooks with several yards of rope attached to each are inserted in either side of the victim's back. He is then conducted to a raised platform or staging upon which he is bound to a long cross-pole pivoted on a tall upright post in such a way as to admit of his being first raised to the necessary height and then rotated. The whole of the man's weight is borne by as much of the fleshy part of his back as is taken up by the hooks, and he is tied close up to the cross-pole without the ropes being passed round his body.

Hook-swinging is frequently recorded from the sixteenth century onwards, and a careful examination of these records goes to show that it is a Dravidian or aboriginal, and not a Hindu rite.

No satisfactory account of its origin and significance appears yet to have been given, the one suggested by Dr. J. G. Frazer in a note on 'Swinging as a Magical Rite' appended to 'The Dying God' being apparently based on the assumption that hook-swinging is synonymous with swinging on hooks, whereas this is not the case. Suspension and rotation are the essential features of the ceremony.

There are grounds for supposing hook-swinging to be a commutated form of human sacrifice. Not only is it found in the area in which we might expect to meet with such a rudimentary form, but the circumstances in which it is

[1] To be published in *Man*.
[2] To be published in *Folklore*.

practised and the occasions upon which it takes place lend support to this hypothesis. Further, if we examine the well-known Meriah sacrifice of the Khands, we shall find that rotation of the victim was in certain places a very common feature of the ritual, and it is probable that from such form of human sacrifice hook-swinging has descended.

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6. *Sun Cult and Megaliths in Oceania.*
By W. H. R. Rivers, *M.A.*, *M.D.*, *F.R.S.*

The infanticide and libertinage for which the Areois of Eastern Polynesia are best known are probably but late accretions to a cult which had a definitely religious purpose. Moerenhout tells us [1] that in the Marquesas the celebrations of the Areois had a seasonal character, and that their purpose was to represent the annual movements of the sun by the death and coming to life again of the god Hahui.

The Areois of Polynesia closely resemble the secret societies of Melanesia, and the celebrations of some of these have also a seasonal character. Underlying the extortions and licence of the Dukduk of New Britain, there are ideas according to which the rites celebrate the annual death and coming to life again of the Dukduk.[2] We have no direct evidence that the Dukduk, whose birth, life, and death are thus celebrated, represent the sun, but the existence of a definite cult of the sun in the neighbourhood of the region where the Dukduk are active makes this highly probable.[3]

The celebrations of the Matambala of the Solomon Islands also had a seasonal character, and here there is definite evidence that the sun was included among the ritual objects of the societies [4]

In the Tamate or ghost societies of southern Melanesia any evidence of a seasonal character is wanting, but the Tamate are said to be born and to die; and in the ritual of the Tamate Liwoa, or chief society of Mota in the Banks Islands, there are several features which point to a representation of the sun, while the legend which records the origin of the society has several features suggesting that the founder represented the sun.

The representation of the annual movements of the sun by means of the anthropomorphic processes of birth and death is very unlikely to have arisen near the Equator, where these movements are relatively so small. If one purpose of the secret societies of Oceania be the representation of the annual movements of the sun, we should have important confirmation of a conclusion, reached on quite other grounds, that the societies were founded by immigrants into Oceania and that their ritual embodies beliefs and practices brought from elsewhere. The representation of the movements of the sun by such a simile as that of birth and death suggests that the immigrants came from some northern latitude.

There is a striking correspondence in the distribution of the secret societies of Oceania and the presence of structures constructed of large stones. In Tahiti and the Marquesas there are pyramids and platforms made of large stones so worked as to fit closely to one another and form durable structures without cement. The islands in which Oceanic stone-work has reached its highest development are the Carolines, and both here and in the neighbouring Marianne Islands there were societies whose name and functions show them to have been closely akin to the Areois of Eastern Polynesia. Further, there are striking similarities in the narratives recording the foundation of the Areois of Tahiti and the building of the cyclopean structures of Ponape in the Carolines.

In Melanesia, again, the distribution of ancient stone-work corresponds closely with that of secret societies. Structures made of worked stone have been found in only three places, the Banks and Torres Islands and Ysabel in the Solomons. The Banks and Torres Islands are strongholds of the secret cults, and there is a definite tradition that the Matambala of the Solomons came originally from Ysabel.

[1] *Voyage aux Iles du grand Océan*, Paris, 1837, i., 500.
[2] R. H. Rickard, *Proc. Ass. Soc. Victoria*, 1891, iii., 70.
[3] Meier, *Anthropos*, 1912, viii., 706.
[4] Codrington, *Melanesians*, 1891, p. 95.

If there should be established the presence of a sun cult as the main underlying purpose of the secret societies of Oceania, the correspondence of their distribution with that of megalithic structures would provide evidence of great value in relation to the unity of the megalithic culture. It must be noted, however, that we have no evidence of any cult of the sun in Tonga, the megalithic structures of which resemble most closely those of other parts of the world.

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7. *The Bori Cult in Tunis and Tripoli.* *By* Major A. J. N. Tremearne, *M.A.*

There are several kinds of bori. Each Hausa has a familiar of the same sex always with him and another of the opposite sex from puberty until marriage; but there is another kind, not so intimately connected with human beings, and more or less hostile to them. These bori (pl. boruruka, but rarely used) are also known as aljannu (jinns), iblisai (devils), or iskoki (winds). They are everywhere, and though not necessarily evil spirits, a human being has to be exceedingly careful lest he offend any of them. There are two principal divisions—those of the city and those of the forest—the former being mostly Mohammedan marabuts and Arab jinns, the others pagan nature-gods and ghosts of ancestors, all being regarded nowadays as disease-demons. Allah is above all, and the bori resemble the courtiers around a Mohammedan throne, since it is better to bribe them first than to address a direct request to the Sovereign.

The Hausa idea of the bori is very vague, but, generally speaking, the spirits have human forms with cloven hoofs, though they can assume any form at will, one (Uwal Yara) being supposed to fly about with the body of a fowl and a human head. Amongst the pagan Hausas, Kuri is the chief bori after Magiro, but since the jinns have been incorporated into the cult many of the Mohammedan spirits rank above the old nature-gods. Magiro, a corn-spirit, is the grandfather of all the bori, however, and after him comes the Leper, usually known as Chief of the Gate (of Jan Gari), or Master of the Horse, so that he may not feel hurt by any reference to his deformities. All bori move like the wind.

The bori live in Jan Gari, the Red City, which is alleged to be situated between Asbero and Aghat. No living person has ever seen the city close, though all travellers across the Sahara are said to know of its whereabouts. Should anyone enter it he will never be heard of more. 'Often when in that district in the early morning travellers have heard the crowing of cocks and other sounds of a city awaking, but on rising they have seen nothing.'

Soothsaying is one of the functions of the masu-bori, though, except as regards sickness, it seems to be dying out. Each member of the sect specialises in certain spirits, and it would be very dangerous for him (or her) to try to get any other bori to 'ride' him. The male performers are known as 'horses,' the female as 'mares' of the bori.

Each temple in Tunis and Tripoli is a long, narrow room in an Arab house, in which are hung the trappings of the dancers and offerings to the bori, those for the young spirits (which give their victims skin complaints and sore eyes) consisting of toys and sweets. Kuri's private apartment is screened off, and must not be entered except by the Arifa, the chief priestess, being a veritable holy of holies. When a new temple is dedicated it is prepared by incense, and fowls are sacrificed. Then the trappings are moved in, and the bori are considered to have taken up their abode.

At the dances an altar is erected and a he-goat (after having been censed and specially fed) and a cock are sacrificed in front of it. Then the bori ride the mounts, and the dances begin, each performer making some characteristic movements (usually indicating the symptoms of the disease), and then sneezing and expelling the spirit.

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8. *A Discussion on a new System of Decipherment of the Hittite Hieroglyphs lately published by the Society of Antiquaries.* By R. Campbell Thompson, *M.A.*

Last November the Society of Antiquaries courteously offered a hearing to my decipherment of the Hittite hieroglyphs, which they are now about to publish in vol. lxiv. of *Archaeologia*. Briefly the steps employed in my decipherment are as follows:—

There have been five previous decipherments, which are practically all different (Sayce, Conder, Jensen, Gleye, and Rusch), and I have, in turn, ventured to differ almost entirely from these. But I must at once acknowledge my indebtedness to Professor Sayce's system for the signs of 'country,' 'god,' 'king' (or 'lord'), the god Tesup, the nominative *s* and a few ideograms, and his brilliant identification of the place-name Tyana, which, by a slight alteration of his values, has provided us with *d*(*t*)*a*, *a*, *n*(*a*). These are the chief points of our agreement, which I have amplified in a note to my article; beyond these our coincidences are rare, particularly in the translations, wherein I can hardly agree at all with him. To Jensen is due the value 'lord' for the 'three strokes' sign, but his system appears to me to be impossible; and the same may be said of the other three. To Peiser is due the division-mark.

My system, briefly, depends, first, on the application of the names of Hittite and other chiefs of the ninth century to the hieroglyphs: and then, with the syllabic values thus obtained, the comparison of the grammar known to us from Hittite cuneiform tablets from Boghaz Keui. By the kindness of the Trustees of the British Museum I was allowed to quote freely from the 1911 inscriptions from Carchemish, particularly one long text of about 600 characters. An elaborate sign occurring twice in one line of a Carchemish inscription led me to give it a provisional value *gar*, on the supposition that it formed part of the names Sangar (a chief of Carchemish) and Gargamis. This apparently gave good results, and thus yielded the values *san*, *n*, *gar*, *g*, and incidentally proved Professor Sayce's *s*. Application of this *g* and *s* to another place-name gave a hypothetical *Ka-r-g-mi-s*, which values were again apparently successful when applied elsewhere. The Hamath inscriptions, by a similar process, yielded *Ir-khu-li-na*, the well-known contemporary of Sangar; and thus, step by step, using the same values, the Hittite inscriptions yielded the following names, which now show that it was a frequent custom to indicate proper names either by a detached stroke or a tang added to a component character:—

(1) *The inscriptions of North Syria and north of this district*: The chiefs *Tesup-*-r* (=Adad-id(?)-r, Adad-idri, Benhadad): *Irkhulina*: *Mutal*, *Muttallu*: '*Aram*, chief of Kask' (=Kashkai: *i.e.* Arame of Bît-Agusi): *Guam* (=Giammu): *Khunu* (=Akhunu): 'the *Kauaut* of *Katte*' (=the tribe Kauai of Katê): *K'ra* (=Kirri, who succeeded Katê): *Ninnas* (=Ninni): *Sangar*: *Kâk* (=Kâki): probably *Lalli* or *Lali* (=Lalli): and a name, probably Shalmaneser, described variantly as *san Asra*, *san Asir*, and *san Ninwis*, 'King of Assyria' and 'King of Nineveh.' Added to these are *Panammi* (=Panammu of Sinjirli) and *Garali* (=Karal, his father): the places *Amd*(*t*)*a* (=Hamath): *Gugum* (=Gurgum): *Kargmis*, *Gargms* (=Gargamis): *Mizir* (=Muzri), and probably *Ams* (=Homs): *T*(*a*)-*bal*(?) (=Tabal): *M*(*W*)*tr* (=Pitru): *Aninna* (=Adinnu): *Umk* (=Amk): *Katnaut* (=the Katnai tribe).

(2) *The inscriptions of Cappadocia*: the King of Tyana, *Araras* (=Ariarathes).

(3) *The inscription of Fraktin*: '*Ma*(?)-*d*(*t*)*a-n-r*, lord of chiefs' (=Muwtallu =the Egyptian form Mautener?).

(4) *A seal, provenance unknown*: *Targu-s-n*(*a*)-*a-li* (=Targashnalli of the Boghaz Keui texts).

These syllabic values provide equivalences between the hieroglyphs and Hittite cuneiform in the verbal terminations and augment, the suffixed pronouns, the pronominal base *kat*, the prepositions *aba*, *ea*, *ta*, *-kan*, *-nda*, *-zi*, and the nom. *-s*, accus. *-n*, and genit. *s* of the noun.

The roots *du* 'to give,' *g* 'to go, come,' *san* 'to make': the verbal augment *a*: and the grammatical terminations: seem to point to an Indogermanic origin for the Hittite language.

The majority of the published inscriptions contain invitations to or records of alliances between the chiefs of the Hittite states, which coincides with what is known from Assyrian, Hebrew, and Aramaic history.

Sub-Section of Physical Anthropology.

The following Papers were read :—

1. *The Evolution of Man from the Ape.*

(i) *On the Differentiation of Man from the Anthropoids.* *By* Professor Carveth Read.

All the prominent characters, functional and structural, that distinguish man from the anthropoids (except his relative nakedness) may be understood as consequences of his having shown a special liking for animal-food. Many primates eat various sorts of animal, but only man can be called carnivorous.

If we suppose that our anthropoid ancestor was adapted to a frugivorous forest life, like the extant anthropoids; that some (or even one) of his species had a liking for animal-food strong enough to lead them persistently to seek it; that this habit was useful by increasing the supply of food, and that it was inherited by their descendants; then differentiation would set in and gradually have the following results :

1. Life on the ground and beyond the limits of the forest.
2. The erect gait as the normal mode of progression with all the changes of bone, joint, and muscle that make this possible.
3. The lengthening of the legs and specialisation of the feet.
4. The shortening of the arms and development of the hands.
5. The use of wrought weapons and snares.
6. Reduction of the size and weight of the jaws and teeth
7. Shortening of the alimentary canal.
8. Association and co-operation for the purpose of hunting, especially the hunting of big game.
9. The beginnings of articulate speech as a means to such co-operation.
10. Great increase of knowledge and intelligence as required by the change of life.
11. Reduction of thickness of skull and increase of its capacity.
12. Discovery of the way to produce fire during the making of weapons of flint or of wood.
13. Loss of seasonal marriage through greater regularity of the supply of food.
14. The great variability of man from race to race and from individual to individual, in stature, colour, size of brain, shape of skull, &c.

Beyond these considerations lie many others concerning the moral and political development of society. Early art, magic, and religion owe much to the savage's intense interest in animals. But to treat of these matters we need many premisses besides the fact that we are beasts of prey. Every advance in culture makes society more complex, and obscures the influence of any one cause.

(ii) *The Factors which have determined Man's Evolution from the Ape.* *By* Harry Campbell, *M.D.*

Man's evolution from the ape has essentially been a mental evolution. Brain and mind have evolved *pari passu* by the continued selection of favourable hereditable variations. Mental, like morphological, evolution proceeds just so far as, but no further than, is needful for adaptive service.

In order that an advance in intelligence may enhance the chance of survival, the individual manifesting the advance must be endowed with the means of turning it to practical account. Only a being possessed of prehensile hands, capable of giving effect to the dictates of mind, could evolve into man; an

of dark, tall, strongly built, Broad-Heads (type 10), and they are also found on other stretches of open coast with bays, &c.—*e.g.*, Newquay, in Cardiganshire. The estuaries of the South-west have a much smaller infusion of this element, but they show numbers of typical Nordics—tall and fair, with narrow or medium heads. In the case of the Teifi, there are few of these near the mouth, where the moorland comes near to the river on either side. A little further up, however, the river has practically isolated a small hill-area in the centre of the valley, and Newcastle Emlyn has been built on it. Here there is a marked patch of Nordics, and the type is generally known in Wales as being characteristic of that region. Our map records only a small number, because in several cases the ancestry was somewhat mixed. Milford Haven and other inlets have the same types, and they are fairly generally distributed on the coast of South Wales.

The fact that there are at least two very distinct coast populations, found usually in different habitats, is interesting. The Welsh chronicles talk of Dark Sea Rovers and Fair Sea Rovers. Type 11 is very generally found with type 10, and its characters often suggest a cross between types 7 and 10, though that is only a guess.

It may be mentioned that the valleyward movement of population, which is such an important consideration as regards the views here advanced, is evidenced in many ways by names of administrative divisions, old-established county boundaries, location of old churches, and so on. It would seem that long ago the bulk of the population in Wales lived above the 600-foot contour, which is now under altered circumstances, approximately the upper limit of anything like dense population.

Collateral lines of inquiry are study of pedigrees for physical character, but this is slow and difficult, and study of the growth features of individuals of various types. This latter inquiry may prove of some interest in adjusting medical and other reports, for these are sometimes very adverse when probably the relevant fact is merely the predominance of the Mediterranean type, with its smaller measurements.

Copies of maps, tabular statements, and cards of ideal examples of various types have been circulated to assist the discussion.

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3. *Early Egyptian Skeletons.*[1]

By Professor W. M. FLINDERS PETRIE, *LL.D.*, *D.C.L.*, *F.R.S.*

Measurements have been published of 892 skeletons before the Twelfth Dynasty, accurately dated, and of 807 more vaguely dated. The cemetery of Tarkhan is the largest group of accurately dated skeletons yet found in Egypt, 600 being all within about one century; and it is of the most important age, that of the settlement of the dynastic people in Egypt. The long bones show details of distribution of variation much more clearly than the skulls.

The casual errors are eliminated by counting in groups of 10 mm. together; and by doing this at every mm. the real variations are more clearly shown.

In the First Dynasty at Tarkhan the female humerus, radius, and clavicle only show the normal distribution curve of a single variable. The similar male curves all show two superposed variables. The bigger one is proportional to the female; the smaller type has no distinct female parallel.

The female and male curves superposed show the male minority clearly, and this is extracted and shown as a separate curve of the excess over the normal curve.

Leg bones apart do not show a distinct grouping, but have a marked grouping when added together. The knee-joint growth is therefore a single unit, the apportionment of which to either bone is indifferent. Besides the clear male minority of four or five per cent., there is a suggestion of a high and a low group of both male and female of about two per cent. of the whole people.

In the whole series of early skeletons the whole leg, humerus, radius, and clavicle follow the same course of changes. From the early prehistoric they diminish down to the smallest type, that of the invading minority race of the

[1] To be published in the *Annual of the British School of Archæology in Egypt.*

First Dynasty, a diminution of eight per cent. Then they increase again about six per cent. up to the Sixth Dynasty.

These changes are not due to gradual evolution, but to racial mixture, as shown by the sudden appearance of a much smaller type superposed on the others in the First Dynasty. The later invasions of Hyksos and Arabs show historically how such changes occur; a gradual infiltration goes on for many centuries—probably impelled by drought elsewhere—until at last a small, compact tribe of invaders enters by force and conquers the already mixed population.

This minority of invaders was about one-ninth of the males in the capital. In the first generation each had three native females, and in the next generation two, in excess of the normal female numbers.

TUESDAY, SEPTEMBER 16.

The following Papers were read :—

1. *The Ideas of the Kiwai Papuans regarding the Soul.* *By* Dr. G. Landtman.

The Kiwai Papuans use the same word for 'soul,' 'shadow,' 'reflection in the water,' and 'picture'; of these the shadow in particular is associated with the soul. A man can steal the soul of somebody else by catching his shadow at night in a piece of bamboo open at one end which he afterwards plugs, and if he wants to kill the other man he burns the bamboo in the fire. Soul and body are to a considerable extent independent of each other; the soul is situated in the head, eye, stomach, or back, or fills up the whole body; different accounts are also given as to the way by which it leaves or enters the body. During a swoon it either withdraws from the body or takes refuge in one of the limbs.

The soul when separated from the body appears, sometimes at any rate, as rather a corporeal being, which can be seen and touched, and in the legends a ghost is often mistaken for a living person. Some malevolent spirits are accompanied by a bad smell, and can be chased away by physical means, and it has even happened that the ghost of a murdered man has been killed a second time. Spirits are, on the other hand, endowed with faculties of their own; they can disappear whenever they choose and suddenly transfer themselves from one locality to another.

The soul can leave the body, which in certain circumstances may for a time live on to outward appearance as if there had been no change. Dreams, which are attributed to the soul wandering about and seeing various things, are implicitly believed in and play a very important part in the life of the natives, as spirits of the dead and other supernatural beings often impart their advice and directions to mortals in this way. Even presents and 'medicines' are at times handed over by the dream-givers to the dreamers. In many cases spirits have passed into men, who have thus become temporarily possessed.

The souls of sick people in particular are in a danger of being removed by malevolent spirits or otherwise, for which reason the sick are watched over by their friends, and certain rules have to be observed for their protection. In a case of a very severe illness the spirit of the sick person is thought to wander about, and several means exist for bringing it back. The soul of a woman in child-bed is often seen to move about of its own accord and may cause mischief to her husband. While a woman is confined her husband may not as a rule go out hunting or fishing, and if he does go he must at any rate first take special measures to prevent the spirit of his wife from following him. In the excitement of a fight the soul of a man may jump out of his body, as shown by the fury of those fighting, and it has in certain cases to be brought back. For the same reason the soul of a murderer comes out of his body and is thought to follow the ghost of his victim at night. People who have the faculty of seeing spirits watch the two apparitions and are sometimes even able to recognise the features of the murderer. His soul can be shot on the spot, which will cause the man's death without any possibility of detecting how it has taken place. People who

have been killed by a crocodile or snake, and also suicides, try to allure their friends into a death similar to their own by first carrying away their souls.

The appearance of the soul of a living man constitutes an omen, and therefore the old men watch in the night before a fight, carefully noting anything they hear and see. If they recognise some warrior's soul, which may sometimes in the dark emit rays of light like blood, that man must not take part in the forthcoming fight or he will be killed. The soul of a man does not necessarily leave the body at the moment when he is being killed, but some time previously in a sort of presentiment. A man may sometimes see his own soul, which forebodes his death; and it happens that the roaming soul of a man, who is about to lose his life on a hunting or fishing expedition, causes mischief to the man himself.

Pigs and dogs have souls, and at all events in some cases when killed go to Adiri, the land of the dead; but there are extremely vague indications only as to any further extension of the belief in souls.

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2. *The Influence of Environment upon the Religious Ideas and Practices of the Aborigines of Northern Asia. By* Miss M. A. Czaplicka.

The term 'environment' must be understood to cover not only strictly physical conditions, but also the botanical and zoological features of a given locality. Environment in this sense is bound to play a large part in determining the nature of the mentality of the inhabitants and in moulding the form of their religious institutions.

This principle may be exemplified by a study of the *shamanism* of Northern Asia. In Northern Asia or Siberia there are two main types of geographical environment, with corresponding variations in the forms of *shamanism* observed there.

1. Along the whole northern section a boundless lowland zone, consisting of *tundra*—a stretch of dreary wastes, exposed to the full fury of Arctic gales, icebound and dark for nine months in the year—presents a typical 'Arctic' landscape. Fishing and hunting can be carried on in summer only, and reindeer-breeding is scarcely possible, owing to the deficient vegetation. The people live for nine months of the year in underground or half-underground houses.

2. Farther south the land rises to the Siberian highlands, whence flow the Ob, Yenisei, and Lena. Here the inhabitants of the steppes lead an open-air, nomadic, pastoral, or hunting life. The climate is 'Continental.'

Two main racial groups inhabit these areas: (*a*) The unclassified Chukchees, Koryaks, Yukaghirs, Kamchadals, Giliaks, &c. (who may be termed Palæo-Siberians); (*b*) the Finnish, Turk, and Mongol tribes (who may be termed Neo-Siberians).

All over Siberian territory there exists the same shamanistic cult, which, as a whole, differs psychologically and sociologically from other animistic and pre-animistic cults.[1] This shamanism is, however, differentiated by the influence of environment into two subordinate types, which may be termed northern and southern.

I. In the north we see the influence of darkness, cold, and scarcity of food on the religious ideas of the people. There is a religious dualism, but the worship of 'black' spirits prevails. Thus even at sacrifices offered to the 'white' (good) spirits the black receive their share. The mental powers are directed towards introspective thinking; hence the prevalence of Arctic hysteria, of revelation, divination, and of sexual perversions. Family shamanism is more important than professional shamanism, which is but slightly developed, since the environment does not encourage social aggregation. Want of light and of suitable materials results in a poor shamanistic apparatus and a poor form of myth-ritual, mostly sexual in content. Arctic hysteria is venerated in so far as it is met with among shamans. The animals on which the people's livelihood depends (whale and other sea animals among maritime tribes; reindeer among reindeer-breeding tribes; bear, wolf, and fox common to both) are the objects of cult, inanimate objects of worship being generally symbols of them. There is no clear idea of

[1] Banzaroff, Klemenz, Khangaloff, Jochelson.

an anthropomorphic god; gods and spirits are mostly half-animals; the distinction between men and animals disappears in myths and in representations of superior beings. Ceremonials are almost exclusively seasonal and are connected with the food supply and with the expulsion of the bad spirits. Incantations form the main substance of the religious practices. The animism of the Palæo-Siberians is marked by the conception of a soul belonging to every part of an animal or thing—the soul of the head, the soul of the breast, &c. In connection with the featureless landscape, the ideal division of the universe is vertical (into upper and lower worlds) rather than horizontal.

II. In the south we find a religious dualism in which the 'white' element prevails. Among the Buriats there are fifty-five 'western' (good) Tengris, and only forty-four 'eastern' (bad) Tengris. Among the Wotiaks the 'white' gods decidedly prevail. In some tribes, the Yakuts and the Altaians, for instance, there is a monotheistic tendency; among the Buriats there is polytheism. Life amid varied scenery, consisting of open country and mountains, has led to worship of the sky and heavenly bodies. Animals, such as the horse, eagle, hedgehog, swan, and snake, are respected, but not worshipped. In the mythology, which is very rich in forms and hyperboles, it is the man, not the animal, that plays an heroic part. Animism is characterised by the idea of a compound soul, usually involving three parts. Comparative abundance of food permits certain spontaneous ceremonial expressions of religious feeling not necessarily connected with the food supply. Imagination is developed and gives rise to fantastic myths. The shaman is a professional; his dress is rich and symbolical. Bloody sacrifices, which in Northern Siberia occur only in a few reindeer-breeding tribes, predominate in the south. The *ongon* is not merely a fetish, as among the Palæo-Siberians, but the image of a god.

Note: The Yakuts, who have migrated from south to north, and the Giliaks, who have migrated from north to south (in Sakhalin), show curious mixtures of the northern and southern types of the shamanistic cult.

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3. *The People of Keftiu and the Isles from the Egyptian Monuments.* *By* G. A. WAINWRIGHT.

Long ago it was suggested by Brugsch that the Egyptian Keftiu = the Hebrew Caphtor and that both = Crete. This supposition was strengthened by the fact that in the paintings of Rekhmara, from which these people are chiefly known, the picture is entitled 'Chiefs of Keftiu' [and] the Isles in the midst of the Sea.' Unfortunately Egyptian phraseology does not specify whether the two words thus joined are in apposition or co-ordinate. Up to the present these two have been read in apposition. The unnamed paintings in another tomb—Senmut—were recognised as representing Cretans of the sixteenth century B.C., and some points in the Rekhmara paintings were recognised as being similar to the Cretan civilisation, and the whole was lumped together as Keftiuan = Cretan.

But on analysis the greater part of the Keftiuan civilisation is not Cretan but Syrian. Besides being shown once with People of the Isles, the Keftiuans are shown twice with Syrians; in the geographical lists the neighbours of Keftiu are grouped about E. Cilicia; the Hymn of Victory groups Keftiu with Asy (at the mouth of the Orontes); in the Canopus Decree Phœnicia is translated by Keftet; a late text calls the Keftiuan language Asiatic; and in a list of Keftiuan names is found one Akashou, which may be the same as the two Philistine names Ikausu of Ekron and Achish of Gath. The Philistines being Caphtorim we are referred to Caphtor once more. But Caphtor is not known to be Crete. The Philistine confederacy consisted of a group of allied tribes, the name of one of which (Cherethites) is translated in the LXX as Cretans. The Caphtorim are translated as Cappadocians. Hence Caphtor is probably Asia Minor, and in Rameses III.'s sculptures of the Pulosatu or Philistines they are shown with an Asia Minor dress and equipment. Therefore the identification of both Keftiu and Caphtor with Crete has come about owing to the presence of Cretans with each of them; these being the People of the Isles with the Keftiuans, and the Cherethites with the Caphtorim or Philistines proper. Keftiu then appears to be Cilicia.

For a view of her civilisation it is necessary to isolate it. To do this a

corpus of that of each extreme—Syria and the Isles—is taken. Out of the 87 Keftiuan objects available for study 60 are found to be of Syrianising types, while 27 are peculiar to Keftiu.

Of the Syrianising types may be mentioned the scale pattern; handles in the form of heraldic animals, an idea stretching from Assyria to Mycenæ; fillers; protomai found in Egyptian paintings to be fairly common in Syria; tusks; lazuli; copper ingots; silver in rings, as from Syria, but also in blocks.

In the native types the goat's head seems to be a favourite *motif*. The vase-handles either rise above the rim in the Ægean style, or are joined flat with it in the Syrian style; they also end either in the Ægean spiral or Syrian flower. The inlaid bull figure is allied to the Mesopotamian types. The Vaphio cup at present must be considered an import, as to-day this type is only known from the Ægean.

The dress of the Keftiuans consists of a pointed ornamented kilt, and sometimes boots. The hair is worn in locks, and twisted into curls on the head, and the beard is generally shaved.

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4. *A Contribution to the Archæology of Cyprus. By* Professor J. L. Myres, *M.A.*

Professor J. L. Myres described some contributions to the archæology of Cyprus which have resulted from recent re-examination of the Cesnola collection of Cypriote antiquities in the Metropolitan Museum of New York. The most important of these are the extension of the upward limit of time for the great series of votive statues, which show a period in which the Assyrian influence which characterises the early half of the seventh century is not yet fully developed, and Syro-Cappadocian affinities are seen; and the discovery that Minoan types of costume, both for men and for women, introduced in the later Bronze Age, remained in ceremonial use, and probably also in daily life, far into the historic period. The Cypriote script now begins to show forms linking it with the Minoan, and Minoan numerals are shown on a Cypriote tablet which seems to be a tribute-list. And among the New York fragments of engraved bowls of Oriental design is one which repeats the subject of the well-known 'Hunting Bowl' found at Palestrina near Rome, and is probably from the same hand and workshop, thus showing the wide distribution of these works of art, and the probability that they are the output of a few closely related centres of industry. One of these centres may very likely have been in Cyprus itself.

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5. *Ancient Assyrian Medicine. By* R. Campbell Thompson, *M.A.*

The principal sources of our knowledge of ancient Assyrian medicine are, of course, the cuneiform tablets of the seventh century from Assurbanipal's palace in Nineveh, now in the British Museum; there are, however, a few references to surgeons in Hammurabi's Code of Laws, written about four thousand years ago, and several incantations for the benefit of sick people dating from the Late Babylonian period. Professor Sayce was one of the earliest to comment on the medical texts proper, and his work was followed many years later by Prof. Küchler's publication on three tablets dealing chiefly with stomachic disorders, which, as is natural in a progressive study, marked a great advance in our knowledge. Since then I have published two small papers on ailments of the head and rheumatism; Drs. Von Oefele and Fonahn have discussed many points on this subject; and Dr. Harri Holma has lately been at pains to collect all the known names of the parts of the body in cuneiform.

There still remain about 500 tablets or fragments of tablets unpublished in the British Museum, which I have been courteously permitted to copy, and hope to bring out shortly, and it is with these chiefly that this paper deals. They relate to diseases of the head, hair, eyes, nose, ears, mouth, teeth, stomach, and other organs; the treatment of pregnancy and difficult travail; poultices, potions, and enemas; and the assuaging of snake-bites or scorpion-stings. The drugs in use can be numbered by the score (there are considerably more than a hundred of them, animal, vegetable, and mineral), but it is obviously often difficult to

identify them with their modern equivalents. This is particularly so in the case of names of plants, for the Assyrian doctors were not content to use each simply, but made compounds of many; and hence arises as great a problem in separating the significance of the components as would apply in future ages to some archæologist in a similar position trying to ascertain the different plants named in the composition of chlorodyne. Nevertheless, several have already long been satisfactorily identified, as, for instance, liquorice, the cassia (probably), and many garden herbs, and the Assyrian word meaning 'hound's-tongue' is shown by Küchler to be the *Plantago major.* I believe that I have been able to identify two narcotics, one, the 'Heart-plant,' as one of the Hyoscyami, some years previously; the other as the mandrake, to be used in allaying headache by continuous application to the head and neck.

In the tablets relating to eye-diseases, the *lish-a-bar* is a drug of fairly common occurrence, and from its connection with the mineral *a-bar* (probably antimony) I see in it the well-known stibium used by Orientals. Another mineral in use for eye troubles is copper dust, in which we may see the forerunner of the more modern sulphate of copper.

This large collection of medical formulæ is distinct from the incantation-texts; the greater number of the sections consists of simple descriptions of the disease followed by a brief receipt for the proper drugs and their use. But even here we find curious lapses into pure magic, such as prescriptions for the use of white and black wool, &c., with appropriate incantations.

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6. *The Female Magician in Semitic Magic.*[1]
By Professor T. Witton Davies, *D.D.*

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7. *Recent Discoveries of the British School in Egypt.*[2]
By Professor W. M. Flinders Petrie, *LL.D., D.C.L., F.R.S.*

In the previous year a great cemetery of the First Dynasty (5500 B.C.) had been partly explored at Tarkhan, about forty miles south of Cairo. This year a valley was cleared and found to contain some 800 more graves closely grouped on each side of an axial road. These were carefully cleared, all the bones measured, the skulls removed whenever possible, plans drawn of each grave and of the whole cemetery, and the form of every vase of stone or of pottery exactly registered. This forms the most complete record yet made of any cemetery. The conquering tribe of the dynastic people had advanced northward from Abydos, subduing the Nile Valley, until Mena founded the new capital of United Egypt at Memphis. Here at Tarkhan was a great settlement, beginning one or two generations before Memphis, and dying away shortly after the new capital was established. What has been uncovered is but a part—probably the smaller part—of the cemetery, which is now mainly under water. Thousands of well-to-do people were buried here within two or three generations, and we must regard this as the pre-Memphite capital of Egypt. This site is therefore the most important centre for studying the critical point of the earliest historical race of Egypt mixing with the prehistoric peoples.

The preservation of the tombs in the cemetery of Tarkhan is remarkable. The earliest stage of the *mastaba* and tomb chapel can here be seen in perfection. The brick wall which retained the pile of sand above the graves, the little slits in it for the soul to come forth to the offerings, the enclosure for the offerings, and the stacks of pottery brought to the grave by the relatives and friends with food and drink for the dead—all were uncovered exactly as they had been left over 7,000 years ago. In the graves were large numbers of alabaster vases, slate palettes, and pottery vases, all of which have been drawn; the types of these, when compared with those of the royal tombs, serve to date the graves to the various reigns shortly before and after Mena. Several blue glazed vases were

[1] Printed in full in the *Expositor*, January 1914.
[2] To be published in the *Annual of the British School in Egypt.* See also 'The Earliest Perfect Tombs,' *Man*, 1913, No. 85.

found, showing that such glazing was commonly in use. As a whole, we get a view of the population, apart from the wealth of the King and Court, and see that they had good furniture, fine vases, and plenty of ornament, and were apparently in quite as civilised a condition as the Egyptians of later ages. The physical character and origin of these people are dealt with in a separate paper (see p. 640).

Another site, at Gerzeh, a few miles further south, has given good results of the Twelfth and Eighteenth Dynasties. Large cemeteries were cleared and some immense stone tombs with chambers as large as those of pyramids. One large tomb had been attacked anciently; the plunderer had crawled in by a small hole, and had begun to remove the ornaments, when the roof fell and crushed him. Thus was saved for our days a gold pectoral inlaid with coloured stones, like the pectorals of the celebrated jewellery of Dahshur, in the Cairo Museum, the only specimen of this splendid work of the Twelfth Dynasty that has been seen in England. With it was part of a similar jewel of Senusert II. and a gold shell of Senusert III.

At Memphis more statuary and sculptures of the Eighteenth and Nineteenth Dynasties have been found, in clearing another acre and a half of the great Temple of Ptah; we further learn that Shishak decorated the temple with a cornice. Gradually the great clearance of this historic site is extended year by year; and it is hoped that the new law, by which the Government claims everything found in private land, will not be exercised to check this work. In the city some workshops have yielded all the various stages of the manufacture of stone vases, from the rough block to the vase spoiled in finishing; other shops contained a great variety of coloured stones brought from the Eastern Desert and from abroad, including the beautiful bright green felspar in granite, not known before. A remarkable standard measure was found, of Ptolemaic age, parallel lines over a foot long being engraved on a slab rather over two feet in length. The accuracy of the scale is finer than a hundredth of an inch; the standard is a cubit of 26·8 inches, known in Egypt under the Eighteenth Dynasty, and used in Asia Minor, classical Germany, and mediæval England.

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8. *The Evolution of the Dolmen.*
By Professor G. ELLIOT SMITH, *M.A.*, *M.D.*, *F.R.S.*

Of all the varieties of the 'rude stone monuments' that are scattered far and wide throughout the world as witnesses to a past and forgotten stage of prehistoric culture, the dolmen is perhaps the commonest, and certainly the crudest, and the type that hitherto has appeared most hopelessly inexplicable.

The aim of this demonstration is to prove that the dolmen represents a degraded form of the typical Egyptian tomb (*mastaba*) of the Pyramid Age. The essential parts of such a tomb in its fully developed form were a deep shaft leading to the subterranean rock-cut burial chamber; a mound of rubble, surrounding the upper opening of the shaft, enclosed within four stone retaining walls, forming an oblong superstructure—the *mastaba*; a chapel of offerings on the side of the *mastaba* facing the River Nile (and as it became the fashion in the Pyramid Age, when the Sun-god, Ra, gained an ascendency in the estimation of the Egyptians, to build these tombs on the west bank the temple thus, as a rule, faced east); in the chapel, let into the eastern wall of the *mastaba,* was a false door or *stela* (symbolic of the means of communication with the dead), before which offerings of food were made to the deceased; and hidden in the *mastaba,* somewhere between the chapel and the shaft leading to the burial chamber, was a chamber—the *serdab*—surrounded and roofed with great slabs of stone, in which a statue of the deceased was placed. The *serdab* was often put into communication with the chapel by means of a narrow, slit-like opening, so that the statue, which 'served as a body for the disembodied dead' (Breasted)—the actual mummy being far away at the bottom of the deep shaft, secure against the desecration of tomb plunderers—might be able to receive the offerings presented in the chapel.

This idea of the dead man's spirit dwelling in the *serdab* appealed strongly to the imagination of a superstitious race, and the conception of the *serdab*

became magnified into the belief in the necessity of providing a house strong enough to endure and prevent the possibility of a houseless spirit wandering at large and making itself a nuisance to the living.

Thus, when the *mastaba* type of grave was made, for example, to bury an Egyptian dying in a foreign land, where skilled craftsmen to carve statues and cut burial shafts deep in the rock were unobtainable, the *serdab* was not only still retained, although there was no statue to put in it, but it even increased in size and importance.

It became a chamber built, in many instances, of huge masses of stone, so as to ensure the permanency necessary to keep the spirit 'at home.' The *stela* likewise persisted, and became the 'holed stone' of the dolmen—the hole being the representative of the slit of communication between the chapel and the *serdab* in the *mastaba*. Sometimes in contemporary subterranean rock-cut tombs imitating the dolmen rough bas-relief were carved upon the inner wall of the *serdab* chamber to represent the status of the old Egyptian tomb; but more often such crude pictures were made on the walls in the chapel (or portico) corresponding to the portraits of the deceased (in the Egyptian tomb) receiving offerings of food, which in the dolmen were often represented symbolically by 'cup-markings.'

The mound of earth and the retaining wall (*i.e.* the *mastaba* proper) were sometimes retained in association with the dolmen, but were not infrequently omitted (or are absent now).

In the Sardinian 'Giants' Tombs' there are represented the *mastaba*, with its retaining wall, the *tumulus*, the *serdab*, a carved *stela*, and a chapel. In the *allée couverte*, so typically seen in France, are represented the chapel, often with very crude portraits of the deceased in bas-relief, the *stela* (holed stone), and the *serdab*, but without the *tumulus* and its retaining wall in many cases. The simplest form of dolmen represents a glorified *serdab*—the home of the disembodied spirit, hovering above the remains of the body in the grave—without a *stela*, but with usually the eastern side open, to represent the door through which offerings of food can be made to the deceased.

9. *Les dernières Découvertes d'Œuvres d'Art paléolithiques dans les Cavernes de la Gaule. Par le* Professeur Dr. CAPITAN.

On sait que depuis un grand nombre d'années on connaissait quelques très jolies sculptures et gravures paléolithiques exécutées sur os, corne ou ivoire et découvertes dans des foyers de l'âge du renne. Depuis treize ans on a signalé en France et en Espagne toute une série de grottes à parois ornées de gravures ou de peintures remontant à l'époque quaternaire.

Depuis quelques mois nos découvertes en Dordogne avec Peyrony et Bouyssonie ont montré qu'il existait une autre variété d'œuvres d'art quaternaires. Ce sont des gravures exécutées sur des dalles ou des blocs de pierre irréguliers de 20 cm. à 70 cm. de largeur rencontrés au milieu des foyers de l'époque magdalénienne à La Madeleine et à Limeuil (Dordogne). Ces très belles gravures non encore publiées sont d'un art très remarquable. Elles représentent surtout des rennes, des chevaux, des bouquetins. Quelques très belles sculptures en ivoire de petite dimension accompagnaient ces pièces.

WEDNESDAY, SEPTEMBER 17.

The following Papers were read:—

1. *Stone-boiling in the British Isles. By* T. C. CANTRILL, *B.Sc., F.G.S.*

The process of boiling water by plunging into it a succession of red-hot stones was in use among most of the northern tribes of North America when that continent first became known to European voyagers, and it survived among the Assinneboins and other primitive peoples down to the early nineteenth century.

The boiling-vessel was a cauldron-shaped hole in the ground, lined with a raw hide; or a hide suspended like a hammock; or a large wooden box, trough, tub, or bowl; or a closely-woven basket of vegetable fibre. Captain Cook found the process in use among the Polynesian islanders, and other travellers have witnessed it, *e.g.*, among the New Zealanders in 1816; among the Esquimaux in 1826; in Australia in 1856; and also in Kamtschatka and South America. A summary account of these extra-European methods was published in 1865 by E. B. Tylor, who pointed out that several limited applications of the principle in comparatively modern times had been recorded in Europe also, viz. in the Hebrides by George Buchanan in 1528; in Ireland in 1600; in East Bothland by Linné in 1732; and in Carinthia by Morlot.

Throughout the British Isles few ancient sites have been explored that have not yielded occasional burnt stones, which have no doubt rightly been regarded as pot-boilers, or as heaters employed in some form of oven. But large heaps of burnt, cracked, and broken stones, mingled with charcoal-dust, although frequent near springs and streams in districts devoid of other evidences of ancient occupation, such as camps, villages, or hut-circles, have seldom been recorded, and, if noted, have not always been understood. To the Irish archæologists belongs the credit of being the first to recognise the origin and meaning of these heaps, though from the Irish records it is probable that there the clue was furnished by tradition. As early as 1815 Horatio Townsend found heaps of burnt stones in co. Cork and regarded them as primitive cooking-places; and since that date similar heaps have been discovered near springs and streams in many parts of Ireland, and in several instances have proved to contain a wooden or clay trough in which the boiling was performed.

In Great Britain a growing volume of evidence supports the view that the practice of stone-boiling once ranged from the Shetlands to the English Channel. In 1865-6 James Hunt and Arthur Mitchell described certain 'tumuli' in Shetland, of wholly abnormal character, which were composed of small, broken, and burnt angular stones and black earth. No interments were found in them, but fragments of burnt pottery were seen, and near—but not within—several of the mounds were found small stone cists. Dr. Mitchell remarked as a peculiarity that most of the Shetland 'tumuli' have one side flattened and depressed. In the particulars recorded of these Shetland remains it is now easy to recognise some of the characteristic features of the Irish cooking-places, and I have no doubt that the supposed tumuli were heaps of pot-boilers, and the cists the boiling-troughs of ancient cooking-places. Traces of stone-boiling have been detected also in Sutherland, in Berwickshire, and in East Lothian.

In the Isle of Man several 'tumuli' of burnt stones have been recorded, but without any suggestion as to their origin. A dug-out oaken trough associated with one of these masses of burnt stones has been described as a canoe; but it is perhaps more likely to have been a boiling-trough, or else a derelict canoe turned to account for cooking-purposes.

The Dartmoor Exploration Committee have detected traces of stone-boiling among the hut sites of Grimspound and elsewhere; and although no heaps of pot-boilers are recorded in the Reports of the Barrow Committee of the Devon Association, the descriptions of certain cairns of unusual character but showing signs of fire are strongly suggestive of the stone-heaps associated with the Irish cooking-places. In Eastern Devon, the late P. O. Hutchinson in 1862 recorded a case where an accumulation of burnt flints at Blackbury Castle, a camp near Colyton, was removed in 1827 and supplied seventy cart-loads of material. In Hampshire, also, similar deposits have been reported from the Forest of Bere; and Mr. Clement Reid, lately my colleague on the Geological Survey, informs me that while quartered in the New Forest he found numerous heaps of burnt flints between Ringwood and Brockenhurst, though he had accounted for them as the relics of prehistoric turf-fires, the stones that were entangled in the fuel having given rise in time to a heap of burnt flints.

In Central and South Wales,[1] with the assistance of several of my colleagues, I have located and described over 270 cooking-places, several of which have yielded worked flints. The mounds range from six to sixty feet in diameter,

[1] T. C. Cantrill and O. T. Jones, in *Archæologia Cambrensis*, 1906, pp. 17-34; 1911, pp. 253-286.

but seldom exceed three feet in height. As no certain traces of wooden troughs have been found, it is probable that the boiling-vessel was a hide-lined hole in the ground, or a hide slung like a hammock.

In Anglesey, Mr. E. Neil Baynes has recently found that some of the cooking places contain a paved hearth.

In South Staffordshire and North Warwickshire, during the past three years we have found fifteen examples near Rugeley, Pelsall, Aldridge, and Middleton, all within reach of Birmingham, the remains consisting of the usual heap of burnt, reddened, and broken pebbles (here quartzites from the Bunter), having much the appearance of road-metal mingled with charcoal-dust, and situated generally near running water.

From the examples quoted above it is clear that stone-boiling was extensively practised in the British Isles in prehistoric times, and doubtless further search will result in similar discoveries in other parts of the kingdom, and may perhaps decide the nature of the cooking-vessel and the period to which the practice should be attributed. It is evident from previous records in the archæological publications that in some cases these heaps of pot-boilers have been mistaken for burial-mounds and for primitive smelting-places. The boiling-troughs, where of wood, have been supposed to be canoes; and where of stone, have been assumed to be sepulchral cists. Sometimes the hearth or floor of the cooking-place was roughly paved with stone slabs and fenced with a low stone wall, and these features have been mistaken for 'stone circles,' or for the lower courses of bee-hive huts. In fine, there is little doubt that certain obscure accumulations of calcined stones disclosed by some of the earlier excavations are explicable as traces of stone-boiling.

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2. *Excavations in the Kinkell Cave, St. Andrews.* *By* Dr. T. J. Jehu *and* A. J. B. Wace, *M.A.*

The Kinkell Cave lies on the cliffs to the east of St. Andrews. The beds of calciferous sandstone exposed in the cliffs here dip to the east at an angle of 33 degrees, and the cave has been made by invasion of the sea along the bedding planes. Excavations were carried on here with a grant from the University of St. Andrews between May 26 and June 12, 1913. The cave was found to have been eroded by the sea prior to the emergence of land, evinced by the 25 feet raised beach, on the lower margin of which it lies. This raised beach records an uplift of land after the appearance of Neolithic man. The cave had been inhabited in Roman and early Christian times. A roughly-laid floor of sandstone slabs was found, and above this a thick deposit from the refuse of human habitation. The central date of this deposit is given by a sherd of *terra sigillata* (Samian ware), found half-way down it. Quantities of shells and animal bones were discovered, all the remains of food. The former are those of limpets, whelks, and periwinkles, common on the shore below. The animal bones are principally those of oxen, sheep, and pigs. The oxen were probably Celtic shorthorns (*Bos longifrons*), and the sheep of the type called *Ovis aries palustris*, and akin to the Soay race. The pig bones include many boar-tusks—interesting in view of the historical traditions as to the prevalence of wild boars in Fifeshire. On the top of this stratum a slab of red sandstone, with incised crosses, was discovered, which probably belongs to the early Christian period.

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3. *The Early Bronze Age in the Lower Rhone Valley.* *By* H. J. E. Peake.

A survey of the implements found in the lower valley of the Rhone shows that the inhabitants of this part of France were only slightly acquainted with the use of metal during the earlier phases of the Bronze Age. A map showing the distribution of flat celts throughout this area seems to indicate that during the first Bronze Period the people were in a neolithic state of culture, though a few bronze implements had reached the edge of the area either from Switzerland or from the north-west. A comparison between the numbers found here and those found in equal areas of Great Britain or Germany is very striking. The

distribution of flanged celts shows that though metal was then known in this region, its use was confined to certain areas. More than one line seem to radiate from the pass of Mont Genêvre, the most conspicuous of these passing to the south-west in the direction of Narbonne. This seems to indicate a line of trade between the Po Valley and the copper mines of Spain.

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4. *Trade between Britain and France in the Neolithic and Bronze Ages. By* O. G. S. Crawford, *M.A.*

The evidence for trade between two peoples rests upon the discovery in the country of objects of either foreign type or foreign material. The discovery of green-stone axes in a county like Hampshire (where no such rock occurs) is an instance. When the axe resembles in shape those made in, *e.g.* Brittany, where the stone occurs naturally, we may infer intercourse, probably commercial, between Brittany and England. The evidence for bronze axes rests mainly upon the type; but this is very clearly marked. Since the publication of 'Ancient Bronze Implements' in 1881 numerous additions have been made to the number of axes of French type found in Britain. This paper was an attempt to give a complete list up to date and to point out certain features in their distribution which are interesting geographically. The question was raised : How far is St. Catherine a mediæval successor of an earlier patron deity of travellers?

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5. *Palæolithic 'Guillotine' Trap-stones. By* Rev. F. Smith.

In the course of nearly fifty years' investigations of relics of prehistoric man, several distinct and, as I believe, incontrovertible phases of such relics have come to hand. These may be classified as 'orthodox' and abnormal weapons; knives, flayers, choppers, grinding or rubbing stones, piercers, disc-stones, clubs, javelin-heads, &c. Among those assumed to be relics none are more conspicuous in my collection than a series which I have described as 'guillotine' trap-stones. They are a type of weapon which is still in use in various parts of the world in the form of a suspended block of wood in the lower end of which a knife is affixed. This is intended to fall upon a passing animal.

If prehistoric man were a strategic hunter, we may naturally assume that very early in his career he learned to throw down his missile upon a passing quarry or enemy, which became in time a heavy pointed stick; and finally, with greatly enhanced effect, a pointed stone. In any case we can imagine that an early pointed stone weapon was sooner or later hurled down from a tree with effect. For at least thirty years I have been puzzled by the abnormal size of what appeared to me as elaborations in stone, sometimes of recognised palæolithic type forms, sometimes of no recognisable form, but with an obvious artificially sharpened point at one end. Several are over forty pounds in weight. They are too large to have been used in the hand, but they all suggest in a variety of ways their intended purpose of being slung. Some are deliberately winged at the top, or left purposely widened. Often a portion is hammered away literally so as to give a hold to a cord or (probably) strips of skin.

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6. *Prehistoric Horse Remains in the Stort Valley, etc. By* A. Irving, *D.Sc., B.A.*

The present communication is a sequel to that made to Section H at the Portsmouth Meeting, 1911.[1] Teeth and limb bones have since come to hand which fall into two series : (1) those of a horse of the Stortford-Grimaldi-Starnberg type; (2) those which answer to the 'Solutrean' (*Equus robustus*) type of Prof. J. C. Ewart.[2] They have been found for the most part in and under the bottom of the 'Rubble-Drift' of the valley, as that has been laid

[1] *B. A. Report* (1911), pp. 521, 522.

[2] J. C. Ewart, F.R.S., on the 'Restoration of an Ancient British Race of Horses' (*Proc. R. Soc. Edin.* vol. xxx., Part 4, pp. 304, 305, fig. 23).

open in a continuous trench (3 ft. 9 in. to 4 ft. in depth) across the valley of the Stort nearly a mile and a half long for the purpose of laying down a new water-main.[3] Others have been found in the excavation, which was carried down to 4 feet below the present bed of the River Stort into the solid peat, for the foundation of a pier-wall in widening the bridge at the side of the old Town Mill.[4] These are supplemented by remains from Braintree collected by the Rev. J. W. Kenworthy.

Remains which tally with those of the Stortford Skeleton.

1. *Molars of the Cheek Dentition* (18 specimens).

(*a*) From the output of the M. A. pond-excavation in which the skeleton was unearthed, p.m. 2, p.m. 3 (extremely decayed by the action of bog-solvents).

(*b*) From the Watermain Trench, p.m. 3, p.m. 4, m. 1 (two).

(*c*) From the site of the 'bronze-hoard' at Matching,[5] p.m. 2, p.m. 3.

(*d*) From Braintree, p.m. 2, p.m. 3 (three), p.m. 4, m. 1 (two), m. 2 (two), m. 3.

2. *Metacarpals.*—One from London Road Sewer Trench—index 6.50; one from Braintree—index 6.43.

3. *Metatarsals.*—One from Bridge Excavation—index 8.00; one from the same (a foal)—index 8.55.

Fragments of other bones (angle of *mandibular ramus*, 'condyle' of *ramus*, and *humerus*) from beneath the 'rubble-drift' tally (in size and otherwise) with the corresponding bones of the skeleton. The evidence here formulated gives (it is submitted) support to the conclusion drawn from the evidence to hand two years ago, that in the Stortford skeleton we have an example of 'an ancient British variety of a race of Horse, which in prehistoric times was widely distributed over Europe.'

Bones and teeth of *Bos* are more numerous than those of *Equus*; remains of *Cervus elaphus*, *Sus* and *Ovis* have been found. A skull of *Lupus* or large dog (with fourteen teeth in place) was found in the excavation below the river-bed.

The remains of *Equus robustus* type are dealt with in a separate note to Section D.

[3] See *Herts and Essex Observer* (Feb. 8, 1913).

[4] *Ibid* (June 14, 1913).

[5] Found about twenty years ago; now in the Colchester Museum.

SECTION I.—PHYSIOLOGY.

PRESIDENT OF THE SECTION.—F. GOWLAND HOPKINS, M.A., D.Sc., F.R.S.

THURSDAY, SEPTEMBER 11.

The President delivered the following Address:—

The Dynamic Side of Biochemistry.

IN the year 1837 Justus Liebig, whom we may rightly name the father of modern animal chemistry, presented a Report to the Chemical Section of the British Association, then assembled at Liverpool. The technical side of this report dealt with the products of the decomposition of uric acid, with which I am not at the moment concerned, but it concluded with remarks which, to judge from other contemporary writings of Liebig, would have been more emphatic had the nature of his brief communication permitted. Liebig had a profound belief that in the then new science of Organic Chemistry, Biology was to find its greatest aid to progress, and his enthusiastic mind was fretted by the cooler attitude of others. In the report I have mentioned he called upon the chemists of this country to take note of what was in the wind, and while complimenting British physiologists and biologists upon their own work, urged upon them the immediate need of combining with the chemists. Ten years later, Liebig had still to write with reference to chemical studies: 'Der Mann welcher in der Thierphysiologie wie Saussure in der Pflanzenphysiologie die ersten und wichtigsten Fragen zur Aufgabe seines Lebens macht, fehlt noch in dieser Wissenschaft.'[1] Much later still, he was still making the same complaint. As a matter of fact, the combination of chemistry with biology, in the full and abundant sense that Liebig's earlier enthusiasm had pictured as so desirable, never happened in any country within the limits of his own century, while in this country, up to the end of that century, it can hardly be said to have happened at all. But the regrettable divorce between these two aspects of science has been so often dwelt upon that you will feel no wish to hear it treated historically, and perhaps even any emphasis given to it now may seem out of place, since on the Continent, and notably in America, the subject of Biochemistry (with its new and not very attractive name) has come with great suddenness into its kingdom. Even in this country, the recent successful formation of a Biochemical Society gives sure evidence of a greatly increased interest in this borderland of science. Yet I am going to ask you to listen to some remarks which are a reiteration of Liebig's appeal, as heard by this Association three quarters of a century ago.

For one can, I think, honestly say that it is yet a rare thing in this country to meet a professed biologist, even among those unburdened either with years or traditions, who has taken the trouble so to equip himself in organic chemistry as to understand fully an important fact of metabolism stated in terms of structural formulæ. The newer science of Physical Chemistry has made a more

[1] *Ann. Chem. Pharm.* lxii., 257, 1847.

direct appeal to the biological mind. Its results are expressed in more general terms and the bearing of its applications are perhaps more obvious, especially at the present moment. This fact increases the danger of a further neglect in biology of the organic structural side of chemistry, upon which, nevertheless, the whole modern science of intermediary metabolism depends. On the other hand, I think one may say that there are only a few among the present leaders of chemical thought in our midst who have set themselves to appraise with sympathy the drift of biological processes or the nature of the problems that biologists have before them. Anyone wishing to see the number of biochemical workers increased might therefore with equal justice appeal to the teachers of biology or to the teachers of chemistry for greater sympathy with the borderland. It is a moot point indeed as to which is the better side for that borderland to recruit its workers from.

But on the whole it is easier for the intelligent adult mind to grasp new problems than to learn a new technique. It is better that youth should be spent in acquiring the latter. That is why, though I admit that it would have been more obviously to the point if made some ten years ago, I feel justified in repeating to-day the appeal of Liebig to the leading chemists of this country, in the hope that they may see their way to direct the steps of more of their able students into the path of Biochemistry. I have been specially tempted to do this, rather than to speak upon some of many subjects which would have interested this section more, for a very practical reason. I have been in a position to review the current demand of various institutions, home and colonial, for the services of trained biochemists, and can say, I think with authority, that the demand will rapidly prove to be in excess of the supply. It will be a pity if the generation of trained chemists now growing up in this country should not share in the restoration of this balance. You certainly have the right to tell me that I ought, under the circumstances, to be addressing another section; but it may be long before any member of my cloth will have the opportunity of appealing to that section from the position of advantage that I occupy here. I believe you will forgive the particular trajectory of my remarks, because I am sure you will sympathise with their aim. Moreover, I have some hope that the considerations upon which I shall chiefly base my appeal will have some interest for members of this section as well as for the chemist. My main thesis will be that in the study of the intermediate processes of metabolism we have to deal, not with complex substances which elude ordinary chemical methods, but with simple substances undergoing comprehensible reactions. By simple substances I mean such as are of easily ascertainable structure and of a molecular weight within a range to which the organic chemist is well accustomed. I intend also to emphasise the fact that it is not alone with the separation and identification of products from the animal that our present studies deal; but with their reactions in the body; with the dynamic side of biochemical phenomena.

I have made it my business during the last year or two to learn, by means of indirect and most diplomatic inquiries, the views held by a number of our leading organic chemists with respect to the claims of animal chemistry. I do not find any more the rather pitying patronage for an inferior discipline, and certainly not that actual antagonism, which fretted my own youth; but I do find still very widely spread a distrust of the present methods of the Biochemist, a belief that much of the work done by him is amateurish and inexact. What is much more important, and what one should be much more concerned to deny (though but a very small modicum of truth is, or ever was, in the above indictment), is the view that such faults are due to something inherent in the subject.

My desire is to point out that continuous progress, yielding facts which, by whomsoever appraised, belong to exact science, has gone on in the domain of animal chemistry from the days of Liebig until now, and that if this progress was till recently slow, it was, in the main, due to a continuance of the circumstance which so troubled Liebig himself—the shortage of workers.

But we must also remember that the small band of investigators who concerned themselves with the chemistry of the animal in the latter half of the nineteenth century suffered very obviously from the fact that the channels in which chemistry as a whole was fated to progress left high and dry certain regions of the utmost importance to their subject. In three regions particularly the needs of Biochemistry were insistent. The colloid state of matter dominates

the milieu in which vital processes progress, but, notwithstanding the stimulating work of Graham, the pure chemist of the last century consistently left colloids on one side with a shudder of distaste. Again, we have come to recognise that the insidious influence of catalysts is responsible for all chemical change as it occurs in living matter, but for many years after Berzelius the organic chemist gave to the subject of catalysis very cursory attention, fundamental though it be. Lastly, every physiological chemist has to realise that among his basal needs is that of accurate methods for the estimation of organic substances when they are present in complex mixtures. But the organic chemist of the nineteenth century did not develop the art of analysis on these lines. Of the myriad substances, natural or artificial, known to him at the most a few score could be separated quantitatively from mixtures, or estimated with any accuracy. It was a professional or commercial call rather than scientific need which evolved such processes as were available, so that this side of chemical activity developed only on limited and special lines.

All these circumstances were, of course, inevitable. Organic chemistry in Liebig's later years was concerned with laying its own foundations as a pure science, and for the rest of the century with building a giant, self-contained edifice upon them. The great business of developing the concepts of molecular structure and the wonderful art of synthesis were so absorbing as to leave neither leisure nor inclination for extraneous labours. But it is easy to recognise that, near the beginning of the present century, a sense of satiety had arisen in connection with synthetic studies carried out for their own sake. Workers came to feel that, so far as the fundamental theoretical aspects of chemistry were concerned, that particular side of organic work had played its part. In numerous centres, instead of only in a few, quite other aspects of the science were taken up: in particular, the study of the dynamic side of its phenomena. The historian will come to recognise that a considerable revolution in the chemical mind coincided roughly with the beginning of this century. Among the branches which are fated to benefit by this revolution—it is to be hoped in this country as well as others—is the chemistry of the animal.

But I would like to say that I do not find, on reading the contributions to science of those who, as professed physiological chemists, ploughed lonely furrows in the last century, any justification for the belief that the work done by them was amateurish or inexact; no suggestion that anything inherent in the subject is prone to lead to faults of the kind. Truly these workers had to share ignorance which was universal, and sometimes, compelled by the urgency of certain problems, had perforce to do their best in regions that were dark. But they knew their limitations here as well as their critics did, and relied for their justification upon the application of their results, which was often not understood at all by their critics.

There is little doubt, for instance, that it was the earlier attempts of various workers to fractionate complex colloid mixtures that led to the cynical statement that '*Thierchemie* is *Schmierchemie*.' But the work thus done, even such work as Kühne's upon the albumoses and peptones, had important bearings, and led indirectly to the acquirement of facts of great importance to physiology and pathology.

In connection with enzyme catalysis the work done at this time by physiological chemists was in the main of a pioneer character, but it was urgently called for and had most useful applications. By the end of the century, indeed, it had become of great importance. I recall an incident which illustrates the need of suspended judgment before work done in new regions is assumed to be inexact. In 1885 E. Schütz published a study of the hydrolysis of protein by pepsin which showed that the rate of action of the ferment is proportionate to the square root of its concentration. When this paper was dealt with in Maly's 'Jahresbericht' the abstractor (who from internal evidence I believe was Richard Maly himself) believed so little in such an apparent departure from the laws of mass action that he saw fit to deal with the paper in a ribald spirit and to add, as a footnote to his abstract, the lines:

'Musst mir meine Erde
Doch lassen steh'n
Und meine Hütte die du nicht gebaut!'

Yet it is now known that the relation brought to light by Schütz does hold for certain relative concentrations of ferment and substrate. That it had limitations was shown by Schutz himself. The fact, however, involves no such shaking of the foundations as the abstractor thought. We quite understand now how such relations may obtain in enzyme-substrate systems.

As for analytical work involving a separation of complex organic mixtures the biochemist of the last century was in this ahead of the pure organic chemist, as the development of urinary analysis if considered alone will show.

In countless directions the acquirement of exact knowledge concerning animal chemistry has been, as I have already claimed, continuous from Liebig's days till now. I would like in a brief way to illustrate this, and if I choose for the purpose one aspect of things rather than another, it is because it will help me in a later discussion. I propose to remind you of certain of the steps by which we acquired knowledge concerning the synthetic powers of the animal body, apologising for the great familiarity of many of the facts which I shall put before you.

It seems that the well-known Glasgow chemist and physician, Andrew Ure, was the first actually to prove, from observations made upon a patient, that an increased excretion of hippuric acid follows upon the administration of benzoic acid. Wohler had earlier fed a dog upon the latter substance, and decided at the time that it was excreted unchanged; but when, later, Liebig had made clear the distinction between the two acids, Wöhler recalled the properties of the substance excreted by his dog, and decided that it must have been hippuric acid and not benzoic acid itself. Excited by the novel idea that a substance thus extraneously introduced might be caught up in the machinery of metabolism, Wöhler, immediately after the publication of Dr. Ure's statement, initiated fresh experiments in his laboratory at Göttingen, where Keller, by observations made upon himself, showed unequivocally that benzoic acid is, and can be on a large scale, converted into hippuric acid in the body. Thus was established a fact which is now among the most familiar, but which at that time stirred the imagination of chemists and physiologists not a little. The discovery immediately led to a large number of observations dealing with various conditions which affect the synthesis, but we may pass to the acute observations of Bertagnini. This investigator wished to earmark, as it were, the benzoic acid administered to the animal, in order to make sure that it was the same molecule which reappeared in combination. He so marked it with a nitro-group, giving nitro-benzoic acid and observing the excretion of nitro-hippuric acid. Later on he continued this interesting line of research by giving other substituted benzoic acids, and showed that in each case a corresponding substituted hippuric acid was formed. Even so far back as the earlier 'fifties a clear understanding was thus established that the body was possessed of a special mechanism capable of bringing a particular class of substances into contact with the amino-acid glycine, and of converting them, by means of a synthetical condensation (which had not then been induced by any laboratory method), into conjugates which, as later experiments have shown, are invariably less noxious for the tissues than the substances introduced. Great is the number of compounds which are now known to suffer this fate. To the story begun by Ure and Wöhler, chapter after chapter has been added continuously up to the present day. In 1876 came the classical experiments of Bunge and Schmiedeberg. After laborious but successful efforts to obtain a good method for the estimation of hippuric acid in animal fluids, these authors proved, by a method of exclusion, that, in the dog at least, the kidney is the seat of the hippuric synthesis. When, in their carefully controlled experiments, blood containing benzoic acid and glycine was circulated through that organ, after its isolation from the body, the production of hippuric acid followed. Schmiedeberg, a little later, convinced himself that the reaction in the kidney was a balanced one; the organ can not only synthesise hippuric acid, it can also hydrolise it. As with reactions elsewhere, so in the kidney cell, the equilibrium of the reaction depends on the relative concentration of the products concerned. Schmiedeberg then separated from the tissues of the kidney what he believed to be an enzyme capable of inducing the hydrolysis. Mutch, with improved methods, has recently shown that a preparation from the kidney, wholly free from intact cells, can, beyond all doubt, hydrolise hippuric acid under rigidly

aseptic conditions, the reaction being one which comes to an equilibrium point when some 97 per cent. of the substance is broken down. The occurrence of this equilibrium, and the form of the reaction-velocity curve as obtained by Mutch, suggested that synthesis under the influence of the enzyme was to be expected, and, on submitting the mixture of benzoic acid and glycine to its influence, Mutch obtained a product which, though too small in amount for analysis, was almost certainly hippuric acid. I have myself obtained evidence which shows that the synthesis does certainly occur under these conditions.

The significance of this earliest known synthesis in the body is no limited one. The amide linkage established by it is one with which the body deals widely, and is, of course, of the type which is dominant in tissue complexes, since it is one which unites the amino-acids in the protein molecule.

Seeing, from the nature of the material supplied for the synthesis by the body itself, that the foreign substances administered must intrude themselves into the machinery of protein metabolism, it is not surprising that many have turned their minds to consider how far a detailed study of the phenomena might throw light upon this machinery. How far can the body extend its supply of glycine when stimulated by increasing doses of benzoic acid? What effects follow when administration is pushed to its limits? How is the fate in metabolism of the whole molecule of protein affected when one particular amino-acid is inharmoniously removed? Can the amino-acid be itself synthesised *de novo* in response to the call for it? These and similar questions clearly arise. I can only stop to remind you that there is evidence that, in connection with this particular chemical synthesis, the carnivore reacts differently to the herbivore. If the body of the former be flooded with benzoic acid, only a proportion undergoes condensation. Only so much glycine is supplied as would correspond, roughly, at any rate, with that rendered available by the normal contemporary breakdown of protein, whereas, in the herbivorous animal, pushing the administration of benzoic acid may lead to the excretion of so much conjugated glycine that it may contain more than half of the whole nitrogen excreted. This is, of course, much more than could come from the protein of the body, and it would seem that the amino-acid is prepared *de novo* for an express purpose, a significant thing. But I must not stop to consider questions which are still in course of study. Before the hippuric synthesis was first observed synthetic powers were thought to be absent from the animal. Since then we have been continuously learning of fresh instances of synthesis in the body, not only in connection with its treatment of foreign substances, with which I am just now concerned, but in connection with all its normal processes.

Another most interesting group of syntheses in which substances are so dealt with in the body as to reappear in conjugation with protein derivatives are those in which the sulphur group plays its part. In 1876 Baumann first introduced us to the ethereal sulphates of the urine, and, from much subsequent work, we know how great a group of substances, chiefly those of phenolic character, are, after administration, excreted linked to sulphuric acid. We have evidence to show that, in all probability, the original condensation is not with sulphuric acid itself, but that oxidation of a previously formed sulphur containing conjugate has preceded excretion, and we know that another group of substances leave the body combined with unoxidised sulphur. Certain cyanides—the aliphatic nitriles, for example—reappear as sulpho-cyanides; but above all in interest is the case described by Baumann, in which the intact cystein complex of protein, after suffering acetylation of its amino group, is excreted as a conjugate. The administration of halogen-benzene compounds is followed by the appearance of the so-called mercapturic acids in which the cystein is linked by its sulphur atom to the ring of chlor-, bromo-, or iodi-benzene. That large amounts of these conjugates can be formed during the twenty-four hours is certain, but it would be interesting to know what limit is set to this loss of cystin from the body.

I will now recall to you syntheses in which the substance supplied by the body is derived, not from protein, but from carbohydrate. The study of the fate of camphor in the body, carried out by Schmiedeberg and Hans Meyer in 1878, if it stood by itself, would abundantly illustrate the significance of this type of experiment. As you are aware, these workers proved that, after the administration of camphor, the urine contains a conjugate formed between

an oxidation product of the camphor and an oxidation product of glucose. Both substances were then new to chemistry, and the latter—glycuronic acid—has since proved itself of great physiological interest. After Schmiedeberg's and Hans Meyer's experiments it was realised for the first time that the sugar molecule might play a part in metabolism quite distinct from its function as fuel, a fact that has much of cogency at the present time. We have good reason to believe that though, as a matter of fact, glycuronic acid is a normal metabolite, the actual synthesis concerns sugar itself, the oxidation of the glucose molecule occurring later. The compound formed is of the glucoside type, and the analogy with the formation of glucosides in the plant is unmistakable. Already the number of substances known to suffer this particular synthesis is legion. Almost every organic group yields an example.

Lastly, in illustration of a quite different type of synthesis (I can only deal with a few of the many known cases) we may recall the methylation which certain compounds undergo. The mechanism of this process, as it occurs in the body, is obscure, and its explanation would be of the greatest chemical interest. I must mention only one particular instance investigated by Ackermann. When nicotinic acid is fed to animals, it is excreted as trigonellin, a known vegetable base. This conversion involves methylation, and is of striking character as an instance of the artificially induced production of a plant alkaloid in the animal body.

The full significance of all such happenings will not be understood unless it be remembered that a nice adjustment of molecular structure is in many cases necessary to prepare the foreign substance for synthesis. Preliminary regulated oxidations or reductions may occur so as to secure, for example, the production of an alcoholic or phenolic hydroxyl group, which then gives the opportunity for condensation which was otherwise absent.

I have touched only on the fringes of this domain. The body of knowledge available concerning it has not been won systematically, and the fate of a multitude of other types of organic substances remains for investigation. The known facts have, one feels, an academic character in the view of the physiologist, and even in that of the pharmacologist, to whom we owe most of our knowledge about them. But, in my opinion, the chemical response of the tissues to the chemical stimulus of foreign substances of simple constitution is of profound biological significance. Apart from its biological bearings as the simplest type of immunity reaction, it throws vivid light, and its further study must throw fresh light, on the potentialities of the tissue laboratories.

In a brilliant address delivered before the Faculty of Medicine of the University of Leeds, Lord Moulton likened the process of recovery in the tissues after bacterial invasion to the generation of forces which establish what is known to the naval architect as the 'righting couple.' This grows greater the greater the displacement of a ship, and finally may become sufficient to overpower the forces tending to make her heel over. It is surely striking to realise that the establishment of the 'righting couple' which brings the tissue cell back to equilibrium after the disturbances due to the intrusion of simple molecules calls for such a complex of chemical events, events which ultimately result in the modification of the disturbing substance and its extrusion from the tissues concerned in a form less noxious to the body as a whole.

Oxidation, reduction, desaturation, alkylation, acylation, condensation; any or all of these processes may be brought *de novo* into play as the result of the intrusion of a new molecule into reactions which were in dynamic equilibrium. It is clear that chemical systems capable of so responding to what may be termed specific chemical stimuli must not be neglected by any student of chemical dynamics. The physiologist has for many years been engaged upon careful analyses of the mechanical and electric responses to stimulation. In the phenomena before us we find 'responses' which are equally fundamental. If we do not study them exhaustively we shall miss an important opportunity for throwing light upon the nature of animal tissues as chemical systems.

One reason which has led the organic chemist to avert his mind from the problems of Biochemistry is the obsession that the really significant happenings in the animal body are concerned in the main with substances of such high molecular weight and consequent vagueness of molecular structure as to make their reactions impossible of study by his available and accurate methods. There

aseptic conditions, the reaction being one which comes to an equilibrium point when some 97 per cent. of the substance is broken down. The occurrence of this equilibrium, and the form of the reaction-velocity curve as obtained by Mutch, suggested that synthesis under the influence of the enzyme was to be expected, and, on submitting the mixture of benzoic acid and glycine to its influence, Mutch obtained a product which, though too small in amount for analysis, was almost certainly hippuric acid. I have myself obtained evidence which shows that the synthesis does certainly occur under these conditions.

The significance of this earliest known synthesis in the body is no limited one. The amide linkage established by it is one with which the body deals widely, and is, of course, of the type which is dominant in tissue complexes, since it is one which unites the amino-acids in the protein molecule.

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remains, I find, pretty widely spread, the feeling—due to earlier biological teaching —that, apart from substances which are obviously excreta, all the simpler products which can be found in cells or tissues are as a class mere dejecta, already too remote from the fundamental biochemical events to have much significance. So far from this being the case, recent progress points in the clearest way to the fact that the molecules with which a most important and significant part of the chemical dynamics of living tissues is concerned are of a comparatively simple character. The synthetic reactions which we have already considered surely prepare us for this view; but it may be felt that, however important, they represent abnormal events, while the study of them has been largely confined to determining the end-products of change. Let me now turn to normal metabolic processes and to intermediary reactions.

We know first of all that the raw material of metabolism is so prepared as to secure that it shall be in the form of substances of small molecular weight; that the chief significance of digestion, indeed, lies in the fact that it protects the body from complexes foreign to itself. Abderhalden has ably summarised the evidence for this and has shown us also that, so far as the known constituents of our dietaries are concerned, the body is able to maintain itself when these are supplied to it wholly broken down into simple *Bausteine*, any one of which could be artificially synthesised with the aid of our present knowledge. Dealing especially with the proteins, we have good reason to believe that the individual constituent amino-acids, and not elaborate complexes of these, leave the digestive tract, while Folin, Van Slyke, and Abel have recently supplied us with suggestive evidence for the fact that the individual amino-acids reach the tissues as such and there undergo change. But still more important, when things are viewed from my present standpoint, is the fact that recent work gives clear promise that we shall ultimately be able to follow, on definite chemical lines, the fate in metabolism of each amino-acid individually; to trace each phase in the series of reactions which are concerned in the gradual break-down and oxidation of its molecule. Apart from the success to which it has already attained, the mere fact that the effort to do this has been made is significant. To those at least who are familiar with the average physiological thought of thirty years ago, it will appear significant enough. So long as there were any remains of the instinctive belief that the carbonic acid and urea which leave the body originate from oxidations occurring wholly in the vague complex of protoplasm, or at least that any intermediate products between the complex and the final excreta could only be looked for in the few substances that accumulate in considerable amount in the tissues (for instance, the creatin of muscle), the idea of seriously trying to trace within the body a series of processes which *begin* with such simple substances as tryosin or leucin was as foreign to thought as was any conception that such processes could be of fundamental importance in metabolism. However vaguely held, such beliefs lasted long after there was justification for them; their belated survival was due, it seems to me, to a certain laziness exhibited by physiological thought when it trenched on matters chemical; they disappeared only when those accustomed to think in terms of molecular structure turned their attention to the subject. But it should be clearly understood that the progress made in these matters could only have come through the work and thought of those who combined with chemical knowledge trained instinct and feeling for biological possibilities. Our present knowledge of the fate of amino-acids, as of that of other substances in the body, has only been arrived at by the combination of many ingenious methods of study. It is easy in the animal, as in the laboratory, to determine the end-products of change; but, when the end result is reached in stages, it is by no means easy to determine what are the stages, since the intermediate products may elude us. And yet the whole significance of the processes concerned is to be sought in the succession of these stages. In animal experiments directed to the end under consideration, investigators have relied first of all upon the fact that the body, though the seat of a myriad reactions and capable perhaps of learning, to a limited extent and under stress of circumstances, new chemical accomplishments, is in general able to deal only with what is customary to it. This circumstance has yielded two methods of determining the nature of intermediate products in metabolism. Considerations of molecular structure will, for instance, suggest

several possible lines along which a given physiological substance may be expected to undergo change. We may test these possibilities by administering various derivatives of the substance in question. Only those which prove on experiment to be fully metabolised, or to yield derivatives in the body identical with those yielded by the parent substance, can be the normal intermediate products of its metabolism. All others may be rejected as not physiological. In a second method dependent upon this eclecticism of the body, substances are administered which so far differ from the normal that, instead of suffering a complete breakdown, they yield some residual derivative which can be identified in the excreta, and the nature of which will throw light upon the chemical mechanism which has produced it. For instance, a substance with a resistant (because abnormal) ring structure, but possessing a normal side chain, may be used to demonstrate how the side chain breaks down. Again, we may sometimes obtain useful information by administering a normal substance in excessive amounts, when certain intermediate products may appear in the excreta. Another most profitable method of experiment is that in which the substance to be studied is submitted to the influence of isolated organs instead of to that of the whole animal. Under these conditions, a series of normal reactions may go on, but with altered relative velocities, so that intermediate products accumulate; or again when, as may happen, the successive changes wrought upon a substance by metabolism occur in different organs of the body, this use of isolated organs enables us to dissect, as it were, the chain of events. Extraordinarily profitable have been the observations made upon individuals suffering from those errors of metabolism which Dr. Garrod calls 'metabolic sports, the chemical analogues of structural malformations.' In these individuals, Nature has taken the first essential step in an experiment by omitting from their chemical structure a special catalyst which at one point in the procession of metabolic chemical events is essential to its continuance. At this point there is arrest, and intermediate products come to light.

As you know, most ingenious use of this ready-made experimental material has added greatly to our knowledge of intermediate metabolism. Admirable use, too, has been made of the somewhat similar conditions presented by diabetes, clinical and experimental. Every day our knowledge of the dynamics of the body grows upon these lines.

I know that the history of all these efforts is familiar to you, but I am concerned to advertise the fact that our problems call for ingenuity of a special sort, and to point out that an equipment in chemical technique alone would not have sufficed for the successful attack which has been made upon them. But I am even more concerned to point out that the direct method of attack has been too much neglected, or has been in the hands of too few; I mean the endeavour to separate from the tissues further examples of the simpler products of metabolic change, no matter how small the amount in which they may be present; an endeavour which ought not to stop at the separation and identification of such substances, but to continue till it has related each one of them to the dynamic series of reactions in which each one is surely playing a part. The earliest attempts at tracing the intermediate processes of metabolism looked for information to the products which accumulate in the tissues, but it seemed to be always tacitly assumed that only those few which are quantitatively prominent could be of importance to the main issues of metabolism. It is obvious, however, upon consideration, that the degree to which a substance accumulates is by itself no measure of its metabolic importance; no proof as to whether it is on some main line of change, or a stage in a quantitatively unimportant chemical bypath. For, if one substance be changing into another through a series of intermediate products, then, as soon as dynamical equilibrium has been established in the series, and to such equilibrium tissue processes always tend, the rate of production of any one intermediate product must be equal to the rate at which it changes into the next, and so throughout the series. Else individual intermediate products would accumulate or disappear, and the equilibrium be upset. Now the rate of chemical change in a substance is the product of its efficient concentration and the velocity constant of the particular reaction it is undergoing. Thus the relative concentration of each intermediate substance sharing in the dynamic equilibrium, or, in other words, the amount in which we shall find it at any moment in the tissue, will be inversely proportional to

the velocity of the reaction which alters it. But the successive velocity constants in a series of reactions may vary greatly, and the relative accumulation of the different intermediate products must vary in the same degree. It is certain that in the tissues very few of such products accumulate in any save very small amount, but the amount of a product found is only really of significance if we are concerned with any function [2] which it may possibly possess. It is of no significance as a measure of the quantitative importance of the dynamical events which give rise to it.

To take an instance. The substance creatin has always asserted itself in our conceptions concerning nitrogenous metabolism because of the large amount in which it is found in the muscle. It may be of importance *per se*, and abnormalities in its fate are certainly important as an indication of abnormalities in metabolism, but we must remember that the work of Gulewitsch, Krimberg, Kutscher, and others has shown us that a great number of nitrogenous basic bodies exist in muscle in minute amounts. Maybe we shall need to know about each of these all that we now know, or are laboriously trying to know, about creatin, before the dynamics of basic nitrogen in muscle become clear. Fortunately for the experimenter, most of the raw materials required for tissue analysis are easily obtainable; there is no reason save that of the labour involved why we should not work upon a ton of muscle or a ton of gland tissue.

I am certain that the search for tissue products of simple constitution has important rewards awaiting it in the future, so long as physiologists are alive to the dynamical significance of all of them. Such work is laborious and calls for special instincts in the choice of analytical method, but, as I mentioned in an earlier part of this address, I am sure that high qualifications as an analyst should be part of the equipment of a biological chemist.

I should like now to say a few words concerning the actual results of this modern work upon intermediate metabolism, and will return to the amino-acids. It is clear that what I can say must be very brief.

We know that the first change suffered by an α-amino-acid when it enters the metabolic laboratories is the loss of its amino group, and, thanks to the labours of Knoop, Neubauer, Embden, Dakin, and others, we have substantial information concerning the mechanism of this change. The process involved in the removal of the amino group is not a simple reduction, which would yield a fatty acid, or substituted fatty acid, nor a hydrolytic removal which would leave an α-hydroxy-acid; but the much less to be expected process of an oxidative removal, which results in the production of a keto-acid.[3] If the direct evidence for this chemically most interesting primary change were to be held insufficient (though there is no insufficiency about it), its physiological reality is strongly supported by the proof given us by Knoop and Embden that the liver can resynthesise the original amino-acid from ammonia and the corresponding keto-acid. This profoundly significant observation is part of the evidence which is continually accumulating to show that all normal chemical processes of the body can suffer reversal. The next step in the breakdown involves the oxidation of the keto-acid, with the production of a fatty acid containing one carbon less than the original amino-acid. This in turn is oxidised to its final products along the lines of the β-oxidation of Knoop, two carbon atoms being removed at each stage of the breakdown. All this is true of the aliphatic α-amino-acids, and, with limitations, of the side chains of their aromatic congeners. In the case of certain amino-acids the course of breakdown passes through the stage of aceto-acetic acid. This happens to those of which the molecule contains the benzene ring, and Dakin has enabled us to picture clearly the path of change which involves the opening of the ring. This particular stage does not seem to occur in the breakdown of the aliphatic amino-acids, save in the case of leucin; the

[2] A product of metabolism can only be said to have a 'function' in a cell or in the body when, being the end-product of one reaction, it initiates or modifies reactions in another milieu.

[3] Dakin's recent work is giving us an insight into the mechanism of the keto-acid formation. Amino-acids in aqueous solution dissociate into ammonia and the corresponding keto-aldehyde. The oxidation involved is therefore concerned with the conversion of the aldehyde into the acid.

rule and the exception here being alike easy of explanation by considerations of molecular structure.

But direct breakdown on the lines mentioned is far from being the only fate of individual amino-acids in the body. The work of Lusk, completed by that of Dakin, has shown us that of seventeen amino-acids derived from protein no less than nine may individually yield glucose in the diabetic organism, and there are excellent grounds for believing (indeed, there is no doubt) that they do the same to a duly regulated extent in the normal organism. The remaining seven have been shown not to yield sugar, and there is therefore a most interesting contrast in the fate of two groups of the protein *Bausteine.* Those which yield sugar do not yield aceto-acetic-acid, and those which yield the latter are not glycogenic. One set, after undergoing significant preliminary changes, seems to join the carbohydrate path of metabolism, the other set ultimately joins a penultimate stage in the path which is traversed by fats.

I will here venture to leave for one moment the firm ground of facts experimentally ascertained. Unexplored experimentally, but quite certain so far as their existence is concerned, are yet other metabolic paths of prime importance, along which individual amino-acids must travel and suffer change. We know now from the results of prolonged feeding experiments upon young growing animals, which I myself, as well as many others, have carried out, that all the nitrogenous tissue complexes, as well as the tissue proteins, can be duly constructed when the diet contains no other source of nitrogen besides the amino-acids of protein. The purin and pyrimidin bases, for instance, present in the nuclear material of cells certainly take origin from particular amino-acids, though we have no right to assume that groups derived from carbohydrates or fats play no part in the necessary syntheses. While recent years have given us a wonderfully clear picture as to how the nucleic acids and the purin bases contained in them break down during metabolism, we have as yet no knowledge of stages in their synthesis. But it is clear that to discover these is a task fully open to modern experimental methods, and though a difficult problem, it is one ready to hand. Again, in specialised organs substances are made which are of great importance, not to the structure, but to the dynamics of the body. These have become familiar to us under the name of Hormones. We know the constitution of one of these only, adrenaline. The molecule of this exemplar has a simple structure of a kind which makes it almost certain to be derived from one of the aromatic amino-acids. It is clearly open to us to discover on what lines it takes origin. Facts of this kind, we may be sure, will form a special chapter of biochemistry in the future. I would like to make a point here quite important to my main contention that metabolism deals with simple molecules. As a pure assumption it is often taught, explicitly or implicitly, that although the bowel prepares free amino-acids for metabolism, only those which are individually in excess of the contemporary needs of the body for protein are directly diverted to specialised paths of metabolism, and these to the paths of destructive change. All others—all those which are to play a part in the intimacies of metabolism—are supposed to be first reconstructed into protein, and must therefore again be liberated from a complex before entering upon their special paths of change. But there is much more reason (and some experimental grounds) for the belief that the special paths (of which only one leads to the repair or formation of tissue protein) may be entered upon straightway. Mrs. Stanley Gardiner (then Miss Willcock) carried out some feeding experiments a few years ago, and in discussing these I pointed out that they offered evidence of the direct employment for special purposes of individual amino-acids derived as such from the bowel. It seemed at the time that the argument was misunderstood or felt to carry little weight, but later Professor Kossell[4] quoted my remarks with approval and expressed agreement with the view that the *Bausteine* of the food protein must, in certain cases, be used individually and directly.

I wish I had time to illustrate my theme by some of the abundant facts available from quite other departments of metabolism; but I must pass on.

The chief thing to realise is that as a result of modern research the conception of metabolism in block is, as Garrod puts it, giving place to that of

[4] *Johns Hopkins Hospital Bulletin,* March 1912.

metabolism in compartments. It is from the behaviour of simple molecules we are learning our most significant lessons.

Now interest in the chemical events such as those we have been dealing with may still be damped by the feeling that, after all, when we go to the centre of things, to the bioplasm, where these processes are initiated and controlled, we shall find a milieu so complex that the happenings there, although they comprise the most significant links in the chain of events, must be wholly obscure, when viewed from the standpoint of structural organic chemistry. I would like you to consider how far this is necessarily the case.

The highly complex substances which form the most obvious part of the material of the living cell are relatively stable. Their special characters, and in particular the colloidal condition in which they exist, determine, of course, many of the most fundamental characteristics of the cell: its definite yet mobile structure, its mechanical qualities, including the contractility of the protoplasm, and those other colloidal characters which the modern physical chemist is studying so closely. For the dynamic chemical events which happen within the cell, these colloid complexes yield a special milieu, providing, as it were, special apparatus, and an organised laboratory. But in the cell itself, I believe, simple molecules undergo reactions of the kind we have been considering. These reactions, being catalysed by colloidal enzymes, do not occur in a strictly homogeneous medium, but they occur, I would argue, in the aqueous fluids of the cell under just such conditions of solution as obtain when they progress under the influence of enzymes *in vitro*.

There is, I know, a view which, if old, is in one modification or another still current in many quarters. This conceives of the unit of living matter as a definite, if very large and very labile molecule, and conceives of a mass of living matter as consisting of a congregation of such molecules in that definite sense in which a mass of, say, sugar is a congregation of molecules, all like to one another. In my opinion, such a view is as inhibitory to productive thought as it is lacking in basis. It matters little whether in this connection we speak of a 'molecule' or, in order to avoid the fairly obvious misuse of a word, we use the term 'biogen,' or any similar expression with the same connotation. Especially, I believe, is such a view unfortunate when, as sometimes, it is made to carry the corollary that simple molecules, such as those provided by food-stuffs, only suffer change after they have become in a vague sense a part of such a giant molecule or biogen. Such assumptions became unnecessary as soon as we learnt that a stable substance may exhibit instability after it enters the living cell, not because it loses its chemical identity, and the chemical properties inherent in its own molecular structure, by being built into an unstable complex, but because in the cell it meets with agents (the intracellular enzymes) which catalyse certain reactions of which its molecule is normally capable.

Exactly what sort of material might, in the course of cosmic evolution, have first come to exhibit the elementary characters of living stuff, a question raised in the Presidential Address which so stirred us last year, we do not, of course, know. But it is clear that the living cell as we now know it is not a mass of matter composed of a congregation of like molecules, but a highly differentiated system; the cell, in the modern phraseology of physical chemistry, is a system of co-existing phases of different constitutions.[5] Corresponding to the difference in their constitution, different chemical events may go on contemporaneously in the different phases, though every change in any phase affects the chemical and physico-chemical equilibrium of the whole system. Among these phases are to be reckoned not only the differentiated parts of the bioplasm strictly defined (if we can define it strictly) the macro- and micro-nuclei, nerve fibres, muscle fibres, &c., but the material which supports the cell structure, and what have been termed the 'metaplasmic' constituents of the cell. These last comprise not only the fat droplets, glycogen, starch grains, aleurone grains, and the like, but other deposits not to be demonstrated histologically. They must be held, too—a point which has not been sufficiently insisted upon—to comprise the diverse substances of smaller molecular weight and greater solubility,

[5] See in this connection the very able exposition of the views developed by Zwaardemaker and others, by Botazzi in Winterstein's *Handbuch*, vol. i.

which are present in the more fluid phases of the system—namely, in the cell juices. It is important to remember that changes in any one of these constituent phases, including the metaplasmic phases, must affect the equilibrium of the whole cell system, and because of this necessary equilibrium-relation it is difficult to say that any one of the constituent phases, such as we find *permanently* present in a living cell, even a metaplasmic phase, is less essential than any other to the 'life' of the cell, at least when we view it from the standpoint of metabolism. It is extremely difficult and probably impossible by any treatment of the animal to completely deprive the liver of its glycogen deposits, so long as the liver cells remain alive. Even an extreme variation in the quantity is in the present connection without significance because, as we know, the equilibrium of a polyphasic system is independent of the mass of any one of the phases; but I am inclined to the bold statement that the integrity of metabolic life of a liver cell is as much dependent on the co-existence of metaplasmic glycogen, however small in amount, as upon the co-existence of the nuclear material itself; so in other cells, if not upon glycogen, at least upon other metaplasmic constituents.

Now we should refuse to speak of the membrane of a cell, or of its glycogen store, as living material. We should not apply the term to the substances dissolved in the cell juice, and, indeed, would hardly apply it to the highly differentiated parts of the bioplasm if we thought of each detail separately. We are probably no more justified in applying it, when we consider it by itself, to what, as the result of microscopic studies, we recognise as 'undifferentiated' bioplasm. On ultimate analysis we can hardly speak at all of living matter in the cell; at any rate, we cannot, without gross misuse of terms, speak of the cell life as being associated with any one particular type of molecule. Its life is the expression of a particular dynamic equilibrium which obtains in a polyphasic system. Certain of the phases may be separated, mechanically or otherwise, as when we squeeze out the cell juices, and find that chemical processes still go on in them; but 'life,' as we instinctively define it, is a property of the cell as a whole, because it depends upon the organisation of processes, upon the equilibrium displayed by the totality of the co-existing phases.

I return to my main point. The view I wish to impress upon you is that some of the most important phenomena in the cell, those involving simple reactions of the type which we have been discussing, occur in ordinary crystalloid solution. We are entitled to distinguish fluid (or more fluid) phases in the cell. I always think it helpful in this connection to think of the least differentiated of animal cells—to consider, for instance, the amœba. In this creature a fluid phase comes definitely into view with the appearance of the food vacuole. In this vacuole digestion goes on, and there can be no doubt, from the suggestive experimental evidence available, that a digestive enzyme, and possibly two successive enzymes (a pepsin followed by a trypsin) appear in it. It is now generally admitted that digestion in the amœba, though intracellular, is metaplasmic. The digestion products appear first of all in simple aqueous solution. Is it not unjustifiable to assume that the next step is a total 'assimilation' of the products, a direct building up of all that is produced in the vacuole into the complexes of the cell? If there be any basis for our views concerning the specificity of, say, the tissue proteins, they must apply to the amœba no less than to the higher animal, and we must picture the building-up of its specific complexes as a selective process. The mixture of amino-acids derived from the proteins of the bacteria or other food eaten by it may be inharmonious with their balance in the amœba. Some have to be more directly dealt with, by oxidation or otherwise. If the digestive hydrolysis occur outside the complexes, we may most justifiably assume that other preparative processes also occur outside them. We need not think of a visible vacuole as the only seat of such changes. Similar fluid phases in the cell may elude the microscope, and the phenomena would be just as significant if reactions occur in the water imbibed by the colloids of the cell or present in the intra-micellar spaces of the bioplasm. It is always important to remember that 75 per cent. of the cell substance consists of water.

All of these considerations we may apply to the tissue cells of the higher animal. To my mind, at least, the following considerations appeal. It is noteworthy that all the known complexes of the cell—the proteins, the phosphorous complexes, the nucleic acids, &c.—are susceptible to hydrolysis by catalytic

agents, which are always present, or potentially present. If the available experimental evidence be honestly appraised, it points to the conclusion that only to hydrolytic processes are the complexes unstable. Under the conditions of the body they are, while intact, resistant to other types of change, their hydrolytic products being much more susceptible. Since hydroclastic agents are present in the cell we must suppose that there is, at any moment, equilibrium between the complexes and their water-soluble hydrolytic products, though the amount of the latter present at any moment may be very small. Now, I think we are entitled to look upon assimilation and dissimilation, when very strictly defined, as being dependent upon changes in this equilibrium alone. They are processes of condensation and hydrolysis respectively. Substances which are foreign to the normal constitution of the complexes—and these comprise not only strictly extraneous substances, but material for assimilation not yet ready for direct condensation, or metabolites which are no longer simple hydrolytic products—do not enter or re-enter the complexes. They suffer change within the cell, but not as part of the complexes. When, for instance, a supply of amino-acids transferred from the gut reaches the tissue cell, they may be in excess of the contemporary limits of assimilation; or, once more, individual acids may not be present in the harmonious proportion required to form the specific proteins in the cell. Are we to suppose that all nevertheless become an integral part of the complexes before the harmony is by some mysterious means adjusted? I think rather that the normality of the cell proteins is maintained by processes which precede actual condensation or assimilation. Conversely, when the cell balance sets towards dissimilation, the amino-acids liberated by hydrolysis suffer further change outside the complexes. So when a foreign substance, say benzoic acid, enters the cell, we have no evidence, experimental or other, to suggest that such a body ever becomes an integral part of the complexes. Rather does it suffer its conjugation with glycine in the fluids of the cell. So also with cases of specific chemical manufacture in organs. When, for instance, adrenaline—a simple, definite crystalline body—appears in the cells of the gland which prepares it, are we to suppose that its molecule emerges in some way ready-made from the protein complexes of the gland, rather than that a precursor derived from a normal hydrolytic product of these proteins or from the food supply is converted into adrenaline by reactions of a comprehensible kind, occurring in aqueous solution, and involving simple molecules throughout? While referring to adrenaline, I may comment upon the fact that the extraordinarily wide influence now attributed to that substance is a striking illustration of the importance of simple molecules in the dynamics of the body.

It should be, of course, understood, though the consideration does not affect the essential significance of the views I am advancing, that the isolation of reactions in particular phases of the cell is only relative. I have before emphasised the point that the equilibrium of the whole system must, to a greater or less degree, be affected by a change in any one phase. A happening of any kind in the fluid phases must affect the chemical equilibrium and, no less, the physico-chemical equilibrium, between them and the complexes or less fluid phases. A drug may have an 'action' on a cell, even though it remain in solution, and it may have a specific action because its molecular constitution leads it to intrude into, and modify the course of, some one, rather than any other, of the numerous simple chemical reactions proceeding in the cells of different tissues.

But I must now turn from consideration of the reactions themselves to that of their direction and control. It is clear that a special feature of the living cell is the organisation of chemical events within it. So long as we are content to conceive of all happenings as occurring within a biogen or living molecule all directive power can be attributed in some vague sense to its quite special properties.

But the last fifteen years have seen grow up a doctrine of a quite different sort which, while it has difficulties of its own, has the supreme merit of possessing an experimental basis and of encouraging by its very nature further experimental work. I mean the conception that each chemical reaction within the cell is directed and controlled by a specific catalyst. I have already more than once implicitly assumed the existence of intracellular enzymes. I must now consider them more fully.

Considering the preparation made for it by the early teaching of individual biologists, prominent among whom was Moritz Traube, it is remarkable that belief in the endo-enzyme as a universal agent of the cell was so slow to establish itself, though in the absence of abundant experimental proof scepticism was doubtless justified. So long as the ferments demonstrated as being normally attached to the cell were only those with hydroclastic properties, such as were already familiar in the case of secreted digestive ferments, the imagination was not stirred. Only with Buchner's discovery of zymase and cell-free alcoholic fermentation did the faith begin to grow. Yet, a quarter of a century before, Hoppe-Seyler had written (when discussing the then vexed question of nomenclature, as between organised and unorganised 'ferments'): 'The only question to be determined is whether that hypothesis is too bold which assumes that in the organism of yeasts there is a *substance* [the italics are mine] that decomposes sugar into alcohol and CO_2 . . . I hold the hypothesis to be *necessary* because fermentations are chemical events and must have chemical causes . . .' If in the last sentence of this quotation we substitute for the word 'fermentations' the words 'the molecular reactions which occur within the cell' Hoppe-Seyler would, I think, have been equally justified.

Remembering, however, the great multiplicity of the reactions which occur in the animal body, and remembering the narrow specificity in the range of action of an individual enzyme, we may be tempted to pause on contemplating the myriad nature of the army of enzymes that seems called for. But before judging upon the matter the mind should be prepared by a full perusal of the experimental evidence. We must call to mind the phenomena of autolysis and all the details into which they have been followed; the specificity of the proteolytic ferments concerned, and especially the evidence obtained by Abderhalden and others, that tissues contain numerous enzymes, of which some act upon only one type of polypeptide, and some specifically on other polypeptides. We must remember the intracellular enzymes that split the phosphorous complexes of the cell; the lipases, the amylases, and the highly specific invert ferments, each adjusted to the hydrolysis of a particular sugar. We have also to think of a large group of enzymes acting specifically upon other substances of simple constitution, such as the arginase of Kossel and Dakin, the enzyme recently described by Dakin which acts with great potency in converting pyruvic aldehyde into lactic acid, and many others. Nothing could produce a firmer belief in the reality and importance of the specialised enzymes of the tissues than a personal repetition of the experiments of Walter Jones, Schittenhelm, Wiechowski, and others, upon the agents involved in the breakdown of nucleic acids; each step in the elaborate process involves a separate catalyst. In this region of metabolism alone a small army of independent enzymes is known to play a part, each individual being of proven specificity. The final stages of the process involve oxidations which stop short at the stage of uric acid in man, but proceed to that of allantoin in most animals. It is very instructive to observe the clean, complete oxidation of uric acid to allantoin, which can be induced *in vitro* under the influence of Wiechowski's preparations of the uric acid oxidase, especially if one recalls at the same time, in proof of its physiological significance, that this oxidase, though always present in the tissues of animals, which excrete allantoin, is absent from those of man, who does not.

I will not trouble you with further examples. We have arrived, indeed, at a stage when, with a huge array of examples before us, it is logical to conclude that all metabolic tissue reactions are catalysed by enzymes, and, knowing the general properties of these, we have every right to conclude that all reactions may be so catalysed in the synthetic as well as in the opposite sense. If we are astonished at the vast array of specific catalysts which must be present in the tissues, there are other facts which increase the complexity of things. Evidence continues to accumulate from the biological side to show that, as a matter of fact, the living cell can acquire *de novo* as the result of special stimulation new catalytic agents previously foreign to its organisation.

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It is certain, from very numerous studies made upon the lower organisms, and especially upon bacteria, that the cell may acquire new chemical powers when made to depend upon an unaccustomed nutritive medium. I must be

content to quote a single instance out of many. Twort has shown that certain bacteria of the Coli-typhosus group can be trained to split sugars and alcohols which originally they could not split at all. A strain of *B. typhosus* which after being grown upon a medium containing dulcite had acquired the power of splitting this substance, retained it permanently, even after passage through the body of the guinea-pig, and cultivation upon a dulcite-free medium. Similar observations have been made upon the Continent by Massini and Burri; the latter showed by ingenious experiments that all the individuals of a race which acquires such a new property have the same potency for acquiring it. No one, at the present time, will deny that the appearance of a new enzyme is involved in this adjustment of the cell to a new nutritive medium.

We have not, it is true, so much evidence for similar phenomena in the case of the higher animals. The milk-sugar splitting ferment may be absent from the gut epithelium before birth, and in some animals may disappear again after the period of suckling, but here we probably have to do with some simple alternation of latency and activisation. But among the 'protective' ferments studied by Abderholden we have, perhaps, cases in which specific individuals appear *de novo* as the result of injecting foreign proteins, &c., into the circulation. Consider, moreover, the case of the reactions called out by simpler substances. We have seen that an enzyme separable from the kidney tissue can catalyse the synthesis no less than the breakdown of hippuric acid. Now the cells of the mammalian kidney have always had to deal with benzoic acid or chemical precursors of benzoic acid, and the presence of a specific enzyme related to it is not surprising. But living cells are not likely to have ever been in contact with, say, bromo-benzol, until the substance was administered to animals experimentally. Yet a definite reaction at once proceeds when that substance is introduced into the body. It is linked up, as we have seen, with cystein. Now, this reaction is not one which would proceed in the body uncatalysed; if it be catalysed by an enzyme, all that we know about the specificity of such agents would suggest that a new one must appear for the purpose. I have allowed myself to go beyond ascertained facts in dealing with this last point. But once we have granted that specific enzymes are real agents in the cell, controlling a great number of reactions, I can see no logical reason for supposing that a different class of mechanism can be concerned with any particular reaction.

If we are entitled to conceive of so large a part of the chemical dynamics of the cell as comprising simple metaplasmic reactions catalysed by independent specific enzymes, it is certain that our pure chemical studies of the happenings in tissue extracts, expressed cell juices, and the like, gain enormously in meaning and significance. We make a real step forward when we escape from the vagueness which attaches to the 'bioplasmic molecule' considered as the seat of all change. But I am not so foolish as to urge that the step is one towards obvious simplicity in our views concerning the cell. For what indeed are we to think of a chemical system in which so great an array of distinct catalysing agents is present or potentially present; a system, I would add, which when disturbed by the entry of a foreign substance regains its equilibrium through the agency of new-born catalysts adjusted to entirely new reactions? Here seems justification enough for the vitalistic view that events in the living cell are determined by final as well as by proximate causes, that its constitution has reference to the future as well as the past. But how can we conceive that any event called forth in any system by the entry of a simple molecule, an event related qualitatively to the structure of that molecule, can be of other than a chemical nature? The very complexity, therefore, which is apparent in the catalytic phenomena of the cell to my mind indicates that we must have here a case of what Henri Poincaré has called *la simplicité cachée*. Underlying the extreme complexity we may discover a simplicity which now escapes us. If so, I have of course no idea along what lines we are to reach the discovery of that simplicity, but I am sure the subject should attract the contemplative chemist, and especially him who is interested and versed in the dynamical side of his subject. If he can arrive at any hypothesis sufficiently general to direct research he will have opened a new chapter of organic chemistry—almost will he have created a new chemistry.

It must not be supposed that I am blind to the fact that the phenomena

of the cell present a side to which the considerations I have put before you do not apply. Paul Ehrlich, in his recent illuminating address to the International Congress of Medicine, remarked that if, in chemistry, it be true that *Corpora non agunt nisi liquida*, then, in chemiotherapy, it is no less true that *Corpora non agunt nisi fixata*. Whatever precisely may be involved in the important principle of 'fixation' as applied to drug actions, it remains, I think, true that the older adage applies to the dynamic *reactions* which occur in the living cell. But there are doubtless dynamic phenomena in which the cell complexes play a prominent part. The whole of our doctrine concerning the reaction of the body to the toxins of disease is based upon the fact that when the cell is invaded by complexes other than those normal to it, its own complexes become involved. I must not attempt to deal with these phenomena, but rather proceed to my closing remarks. I would like, however, just to express the hope that the chemist will recognise their theoretical importance. He will not, indeed, be surprised at the oligo-dynamic aspects of the phenomena, startling as they are. When physico-chemical factors enter into a phenomenon the influence of an infinitely small amount of material may always be expected. It is a fact, for instance, as Dr. W. H. Mills reminds me, that when a substance crystallises in more than one form it may be quite impossible to obtain the less stable forms of its crystals in any laboratory which has been 'infected' with the more stable form, even though this infection has been produced by quite ordinary manipulations dealing with the latter. Here, certainly, is a case in which the influence of the infinitesimal is before us. But what I feel should arrest the interest of the chemist is the remarkable mingling of the general with the particular which phenomena like those of immunity display. In the relations which obtain between toxin and anti-toxin, for example, we find that physico-chemical factors predominate, and yet they are associated to a high degree with the character of specificity. The colloid state of matter, as such, and the properties of surface determine many of the characteristics of such reactions, yet the chemical aspect is always to the front. Combinations are observed which do not seem to be chemical compounds, but rather associations by adsorption; yet the mutual relations between the interacting complexes are in the highest degree discriminative and specific. The chemical factor in adsorption phenomena has, of course, been recognised elsewhere; but in biology it is particularly striking. Theoretical chemistry must hasten to take account of it. The modern developments in the study of valency probably constitute a step in this direction.

It is clear to everyone that the physical chemist is playing, and will continue to play, a most important part in the investigation of biological phenomena. We need, I think, have no doubt that in this country he will turn to our problems, for the kind of work he has to do seems to suit our national tastes and talents, and the biologist just now is much alive to the value of his results. But I rather feel that the organic chemist needs more wooing and gets less, though I am sure that his aid is equally necessary. In connection with most biological problems, physical and organic chemists have clearly defined tasks. To take one instance. In muscle phenomena it is becoming every day clearer that the mechanico-motor properties of the tissue, its changes of tension, its contraction and relaxation, depend upon physico-chemical phenomena associated with its colloidal complexes and its intimate structure. Changes in hydrogen-ion concentration and in the concentration of electrolytes generally, by acting upon surfaces or by upsetting osmotic equilibria, seem to be the determining causes of muscular movement. Yet the energy of the muscle is continuously supplied by the progress of organic reactions, and for a full understanding of events we need to know every detail of their course. Here then, as everywhere else, is the need for the organic chemist.

But I would urge upon any young chemist who thinks of occupying himself with biological problems, the necessity for submitting for a year or two to a second discipline. If he merely migrate to a biological institute, prepared to determine the constitution of new products from the animal and study their reactions *in vitro*, he will be a very useful and acceptable person, but he will not become a bio-chemist. We want to learn how reactions run in the organism, and there is abundant evidence to show how little a mere knowledge of the constitution of substances, and a consideration of laboratory possibilities, can help on such knowledge. The animal body usually does the unexpected.

But if the organic chemist will get into touch with the animal, it is sure that the possession of his special knowledge will serve him well. Difficulties and peculiarities in connection with technique may lead the professor of pure chemistry to call his work amateurish, and certainly his results, unlike those of the physical chemist, will not straightway lend themselves to mathematical treatment. He may himself, too, meet from time to time the spectre of Vitalism, and be led quite unjustifiably to wonder whether all his work may not be wide of the mark. But if he will first obtain for us a further supply of valuable qualitative facts concerning the reactions in the body, we may then say to him, as Tranio said to his master :

> 'The mathematics and the metaphysics
> Fall to them as you find your stomach serves you.'

All of us who are engaged in applying chemistry and physics to the study of living phenomena are apt to be posed with questions as to our goal, although we have but just set out on our journey. It seems to me that we should be content to believe that we shall ultimately be able at least to describe the living animal in the sense that the morphologist has described the dead; if such descriptions do not amount to final explanations, it is not our fault. If in 'life' there be some final residuum fated always to elude our methods, there is always the comforting truth to which Robert Louis Stevenson gave perhaps the finest expression, when he wrote :

> 'To travel hopefully is better than to arrive,
> And the true success is labour.'

The following Reports were then read :—

1. *Fifth Interim Report on Anæsthetics.*—See Reports, p. 237.

2. *Report on Colour Vision and Colour Blindness.*—See Reports, p. 258.

3. *Report on the Ductless Glands.*—See Reports, p. 259.

4. *Report on Electromotive Phenomena in Plants.* See Reports, p. 244.

5. *Report on the Structure and Function of the Mammalian Heart.* See Reports, p. 258.

6. *Report on the Dissociation of Oxy-Hæmoglobin at High Altitudes.* See Reports, p. 260.

7. *Report on the Effect of Low Temperature on Cold-blooded Animals.* See Reports, p. 261.

8. *Report on the Occupation of a Table at the Zoological Station at Naples.*—See Reports, p. 153.

FRIDAY, SEPTEMBER 12.

Joint Meeting with the Sub-Section of Psychology.—See p. 678.

MONDAY, SEPTEMBER 15.

Joint Meeting with Section M.

The following Papers were read :—

1. *The Measurement and the Significance of the Hydrogen Ion Concentration in Biological Processes. By* Professor S. P. L. SÖRENSEN.

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2. *Discussion on the Physiology of Reproduction.*

(i) *The Application of Generative Physiology to Animal Husbandry. By* K. J. J. MACKENZIE, *M.A.*

In the regrettable absence of Dr. F. H. A. Marshall, it is proposed to open the discussion from the point of view of the practising agriculturist. The breeding of live stock on the farm has, it is contended, been carried on for many generations without any very great measure of assistance from the man of science.

That the practical breeder's efforts have, on the whole, been successful is not in any way denied—on the contrary, the skill of the practitioner cannot fail to fill the observer with admiration—but it is hoped that this discussion may bring to the notice of physiologists and zoologists some points which demand further scientific investigation. To illustrate this statement some work already done by Dr. F. H. A. Marshall, in association with the speaker, may be instanced as showing that scientific investigation can throw light on the practical difficulties of the breeder and manufacturer. The bacon-curer at the present moment incurs great loss owing to the prevalence of a considerable number of carcases which, on examination immediately after slaughter, are found to have a very valuable 'cut' or joint spoilt by discoloration. One firm of bacon manufacturers estimate their loss from this cause to be several thousand pounds sterling per annum. The popular belief among breeders and manufacturers is that discoloration is due to œstrous changes. It was suggested that ovariotomy prevented this discoloration from appearing. On investigation, the discoloration has been found to be a matter of pigmentation, and that though 'spaying'—as ovariotomy is called by the farmer—may be useful in other ways, it has little, if any, effect in reducing the evil complained of. Having this knowledge, the problem can now be attacked with greater chance of success. Incidentally, whilst working on this problem, Dr. Marshall's investigations into the œstrous cycle in the sow have thrown light on a practical matter in connection with the breeding of swine. A scientific reason has been found, upholding the opinion held by some few only of the very experienced breeders that male and female pigs should be mated at a particular time. In this case science should be of value to the farmer, for up to now the opinion formed on empirical observation has not been strong enough to guide his practice in a direction which involved slightly more trouble.

The frequent occurrence of impotency among sires is a matter in which a long experience of farm animals, and a very inconvenient incident of recent date, force one to the conclusion that scientific research might be usefully employed on behalf of the agriculturist.

Impotence in the male may be temporary or permanent. It is often of incalculable value to the farmer to know which of these two states exists. Yet it would seem that scientific knowledge is such that only too often the farmer is left to let time decide. Work done with a view to seeing if it be possible to give the agriculturist advice about a doubtful sire before it reaches the slaughter-house seems to be demanded. Temporary sterility may, it seems reasonable to believe, be caused by over-service, bad management, mal-nutrition, or other causes. It appears desirable to investigate all conditions governing this state, in the hopes of becoming competent to advise an agriculturist, who often would

derive great pecuniary benefit from the existence of knowledge which would put us in a position to guide him in such difficulties.

Sexual Characteristics.—Almost every text-book on animal husbandry which has appeared in the last hundred years tells the reader that he should choose a sire showing 'male character,' and that such character denotes fecundity, &c.; but the information as to how such character may be recognised is very scanty. It seems necessary to attract the attention of the trained zoologist to such a question to make further progress in our knowledge. For if external indications of these faculties exist, it must be worth while defining and describing their appearance; if they do not exist, frequent mention of them in text-books only adds to the already difficult task of learning to judge stock.

Periodicity.—The practical man has many views upon this point. As many of the views held and expressed are often contradictory to one another, and as the matter is of great commercial importance, it would seem worthy of further investigation.

The Correlation of Fecundity and Productivity.—It is often held by those having charge of milch cows that conception will not take place until any abnormal flow of milk has ceased. The writer's own experience among poultry at one time led him to believe that hens laying a very great number of eggs often failed, through the eggs being 'clear,' to reproduce themselves in great numbers. Both these points seem worthy of further investigation. Even such points as the relative profitableness of a crop of twin lambs, compared with a fall of 'singles,' or the advantage of large and small litters of pigs, ought not to be left severely alone as they have been in the past.

It seems to the writer important for this meeting to discuss the part played by environment, as well as by individuality, in these and all other matters of the kind, for only too often in the past even the scanty data available have been obtained from foreign breeds of live stock living in countries and under conditions other than our own.

(ii) *The Effect of Reproductive Cycle on Glycogen and Fat Metabolism in Crustacea.* By Geoffrey Smith.

In all animals reproductive and growth cycles are probably correlated with metabolic changes in various internal organs. In a large Crustacean, such as *Carcinus mœnas*, it is possible to show that the 'liver,' which corresponds to almost the entire digestive and metabolic apparatus of the higher animals, varies greatly in its composition, according to the condition of the crab in respect to two functions—moulting and reproduction. The composition of the blood also varies in the same way.

If we take crabs with soft shells which have quite recently moulted and determine the percentage of fat and glycogen in the liver, we find a comparatively small amount—from 0·4 to 0·5 per cent. glycogen, and 5 to 10 per cent. fat.[1] The blood is colourless, and yields a small percentage of fat—about 0·05 per cent.

If we take large male crabs with hard shells which are in an intermediate period between two moults, we find a higher percentage of glycogen—one to two per cent.—in the liver, and a larger quantity of this substance under the skin, especially as the crab approaches the period of a fresh moult. The amount of fat in the liver is variable, with an average of about 10 per cent. The blood is generally coloured pink, due to the presence of tetronerythrin which is deposited in the skin. The percentage of fatty material in the blood is about 0·08 per cent. If we take female crabs which are maturing their ovaries preparatory to breeding, we find the liver is richly supplied with fat (13 per cent.), and has a fair quantity of glycogen (1 per cent.), but the most striking feature is that the blood is bright yellow, owing to the presence of lutein, the yellow substance of the yolk which is being formed in the liver and transferred across the blood to the ovary. Analysis of the yellow blood of females shows a very high percentage of fatty material—about 0·2 per cent., or more. After the eggs have been shed the blood becomes colourless again. These internal changes, which differ so

[1] Determinations of fat by Leathes's method, of glycogen by Pfluger's.

much in male and female, have two very obvious external effects: (1) The external colour of the male is redder than the female; (2) the male attains a larger size than the female. These two characters of the male are associated with the formation of tetronerythrin in excess of lutein, and of glycogen in excess of fat.

In crabs of both sexes infected with *Sacculina* we do not find any of these cyclical changes taking place, because such crabs neither grow, moult, nor reproduce. In them we find a remarkably constant internal condition, viz., low percentage of glycogen (about 0·5 per cent.) and a constantly high percentage of fat (13 per cent.). The high percentage of fat is associated with the fact that the *Sacculina* roots absorb large quantities of fat from the crab, which meets the demand by an extra supply. The internal condition of Sacculinised crabs resembles, on the whole, that of female crabs with mature ovaries, except that there is little or no lutein in the blood. The livers of Sacculinised crabs are, however, always yellow with lutein, showing that this substance is formed in large quantities, and perhaps it is seized on by the *Sacculina* roots so rapidly that it does not appear in the blood.

(iii) *The Physiology of Sex Determination. By* Dr. L. Doncaster.

Mr. Geoffrey Smith has shown that the metabolism of fat and other substances is recognisably different in male and female crabs, and that male crabs infected with *Sacculina* tend to have a type of metabolism resembling that of the normal female. Such parasitised males assume more or less completely the female sexual secondary characters, and may go so far as to produce ova in their testes. Somewhat similar phenomena with regard to metabolism have been shown by Steche to exist in Lepidoptera ('Zeitschr. f. indukt. Abstamm.' 8, 1912. p. 284). In the species which he studied the female has green blood, the male yellow, owing to the fact that chlorophyll, or an immediate derivative of it, is present in the blood of the female. The blood of the female differs also in other respects from that of the male, so that he says that there is more difference in the metabolism of the two sexes of the same species than in that of the same sex of different species.

Now breeding experiments with insects and vertebrates have shown apparently conclusively that the determination of sex is due to an inherited factor which is present in one sex and absent in the other; that is to say, that one sex is homozygous in respect of this factor, the other sex heterozygous. But a difficulty arises from the fact that in some groups the female appears to be heterozygous, in others the male. It has been suggested that since in crabs the male may assume the female sex-characters under the influence of *Sacculina*, in this case it is the male which is heterozygous for sex. I wish to put forward a somewhat different suggestion, which would also help to get over the difficulty that although it seems certain that sex is normally determined by an inherited factor, yet there is a good deal of evidence that it may be altered by environmental influences in the embryo, or even in later life, as in the case of the infected crab. I suggest that all individuals, both of animals and plants, contain potentially the factors for the characters of both sexes—that all are, in fact, potential hermaphrodites—but that in addition each individual either receives or does not receive a sex-determining factor, a factor which determines which set of sexual characters shall appear. This determining factor, which is very probably borne in a particular chromosome, does not introduce into the zygote the characters associated with a particular sex—say the female—for these by hypothesis are present in every zygote, but it causes them, rather than the male characters, to develop The characters of the corresponding sex are 'ausgelöst.' as the Germans would say, rather than introduced by the sex-determiner. And the way it does this, on my hypothesis, is by determining a particular form of metabolism. The presence of this factor causes a particular metabolism, and this metabolism causes the female characters to appear; in its absence the metabolism would have been different and the male characters would have appeared. I suggest, in fact, that the type of metabolism determines the sex, and not the sex the type of metabolism. If, then, in a male crab the *Sacculina* induces the type of metabolism characteristic of the female, it is not surprising that female characters appear, even though the crab may have received no inherited female

sex-determiner. The factors for the female characters are present in all individuals, but only appear when 'ausgelöst' by a certain type of metabolism. In the normal female this metabolism is caused by an inherited factor; in the parasitised male the same metabolism is induced by the *Sacculina*, and so the female characters are caused to develop.

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3. *Report on Calorimetric Ovservations on Man.*—See Reports, p. 262.

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4. *Radium Rays in the Treatment of Hypersecretion of the Thyroid Gland. By* Dr. DAWSON TURNER.

Many favourable reports as to the action of the X-rays in disease due to hypersecretion of the thyroid gland have been published. The method of treatment has, in fact, become orthodox. Dr. George R. Murray, in his address in Medicine to the British Medical Association Meeting at Brighton, referred to the use of the X-rays as follows:—

'The application of suitable doses of X-rays to the enlarged thyroid gland has in some of my cases proved to be of great value. The gland gradually diminishes in size, and the other symptoms subside. Atrophic changes in the secretory epithelium and both interstitial and extracapsular fibrosis appear to be induced by the action of the rays. In two of my cases in which X-ray treatment was not successful, the lobe of the gland was excised. Microscopical examination showed no fresh change in one, but a distinct increase in the interalveolar connective tissue of the other. These changes are slow in development, so that the full effect of the treatment is not obtained until some months have elapsed. In favourable cases some fifteen to twenty weekly doses of the rays have been sufficient to bring about great improvement or practical recovery, but in others only slight improvement has followed a similar course of treatment. It is worth while to persevere with X-ray treatment for so long as a year if slow but satisfactory progress is being made. We have, however, still much to learn as to the most appropriate doses and mode of application of this valuable method of treatment.'

In the author's opinion, which is based not only theoretically upon the similarity of physical radiations but also practically upon an experience of four clinical cases, these laudatory remarks as to the action of X-rays could quite as justly be applied to the action of radium. But in addition radium has two distinct clinical advantages over the X-rays: (1) a perfectly definite dose of it can be given and repeated as often as may be desired; (2) the radium can be applied without noise or excitement while the patient is in bed. That this is an important advantage in the treatment of this disease every physician will allow. It was for the latter reason that the author was led to replace the X-rays by radium rays in the treatment of such cases. The clinical results were distinctly favourable, for the tachycardia, breathlessness, and exophthalmos were diminished. Direct histological evidence as to the action of radium on the thyroid gland in the author's cases is wanting, but there is plenty of other evidence available regarding its action on normal and pathological tissues. Thus in nævi the effect is to obliterate the small blood-vessels, and in malignant growths to induce a fibrosis. Professor Oscar Hertwig, of Berlin, in a paper contributed to the recent International Congress, said that radio-active bodies had a powerful influence on vital processes in plants and animals. Many experiments with radium on different tissues showed that while full-grown and differentiated cells and tissues were comparatively little affected, on the contrary, embryonic cells, and others which in adults lingered in an undifferentiated state, especially generative cells, young nerve cells, leucocytes and tumour cells in a state of growth were especially sensitive. Blood and lymph of man, and the hæmatopoietic organs connected with them, were especially altered by radio-active bodies. Microscopically a great diminution in the white corpuscles was observed, caused on the one hand by wholesale disintegration, and on the other by diminution in replenishment.

In some experiments on the nervous tissue by Sir Victor Horsley and

Dr. Finzi it was shown that the action of large doses of filtered radium rays was to infiltrate the meninges with blood, the blood-vessels showing such proliferation of their endothelium that in some cases they were occluded. There was also a considerable formation of fibrous tissue; further, there occurred wedge-shaped thrombotic areas in the cortex. It appears, then, that the most constant histological changes found in nervous tissue after the application of sufficient doses of radium are vascular ones. It is probable, then, that the effect of radium rays on the thyroid gland is to diminish the vascularity of the gland, to cause a diminution in the leucocytes, and an overgrowth in the connective tissues. By these processes the functional activity is lessened, the hypersecretion checked, and the morbid phenomena consequent thereon diminished.

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5. *The Katathermometer. By* Professor LEONARD HILL, *M.B., F.R.S.*

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6. *The Pulse and Resonance of the Tissues. By* Professor LEONARD HILL, *M.B., F.R.S.*

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7. *The Structure of the Post-pericardial Body of the Skate. By* Professor E. W. CARLIER, *M.D.*

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8. *The Relation of the Weight of the Kidneys to the Total Weight of Cats. By* Dr. H. E. ROAF.

In some metabolism experiments on cats, the body weights and the weights of the kidneys were determined. In order to find out the relation of the weight of the kidneys to the body weight, the following method was used. The weights of the kidneys were divided by various powers of the total weights, and the ratios obtained were correlated with the total body weights. The power of the body weight which gives a correlation nearest to zero expresses the relation that the weights of the kidneys have to the body weights.

As the result of forty-eight determinations, the 1·5 power gives a slight positive correlation, and the square of the body weight gives a negative correlation. Some value between these two would give a zero correlation.

Therefore the weight of the kidney increases more rapidly, in proportion, than does the body weight, and that the rate of increase is proportional to some value between the 1·5 power and the square of the body weight. This is remarkable, as most tissues increase in proportion to the body weight or to some power of the same less than unity. The skin and kidneys are interrelated, and it is well known that as the weight increases the skin becomes relatively less. The kidney weight may increase more rapidly in order to compensate for the relative diminution of the skin surface.

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9. *A New Substance in Nerve Cells. By* Professor A. B. MACALLUM, *F.R.S., and* Dr. J. B. COLLOP.

When sections made from perfectly fresh and normal ganglia with CO_2 freezing method are put immediately in a solution of silver nitrate and allowed to remain there exposed to light for an hour, there develops in the cell substance a dark or black reaction which has been found to be characteristic of nerve cells. The substance responsible for this reaction is not diffused throughout the cell,

but is condensed as small granules or in masses in the cytoplasm, and it is wholly absent from the cell nucleus. It occurs also in the polar processes of the cell, but, except in certain sympathetic nerve cells, it does not extend into the axon. The reaction is not due to chlorides or phosphates, and the substance responsible for it is extracted quickly from the cell by water and alcohol. It is most abundant in the cells of the sympathotic nervous system, and it occurs in great abundance in the cells of the nerve ganglia of the leech. It has been found also that the cells of the medulla of the suprarenal glands give the reaction in a marked degree, a point that is of interest since the cells of the medulla of the suprarenals are regarded as altered nerve cells whose function is the secretion of the hormone, adrenalin.

It is suggested that the substance responsible for the reaction belongs to the oxy-phenyl class of compounds, as these readily reduce nitrate of silver in the light, and that it is allied to adrenalin, which is also an oxy-phenyl compound, and which may be prepared from it by the medullary cells of the suprarenal gland. Its occurrence in nerve cells is, apparently, an indication that the nerve cell is, potentially, if not actually, a secreting structure.

TUESDAY, SEPTEMBER 16.

The following Paper was read :—

The Biochemistry of the Neurone. By Dr. F. W. MOTT, *F.R S.*

Joint Meeting with Sections D and K.—See p. 527.

The following Papers were then read :—

1. *Considerations bearing on the Study of the Blood and Vascular System. By* Professor GEORGES DREYER *and* Dr. E. W. AINLEY WALKER.

1. In association with Dr. W. Ray, the authors have already shown that in a series of mammals, both wild and tame, the volume of the blood is proportional to the body surface of the individual throughout any given species. It can be calculated from the formula $B = \frac{W^n}{k}$, where W is the weight of the animal, n is approximately 0·72, and k is a constant to be ascertained for each particular species.

2. Further experiments carried out in association with Dr. H. K. Fry show that in birds the same relation holds, and that the blood volume of fowls, pigeons, sparrows, and ducks follows the formula $B = \frac{Wn}{k}$, n having the value 0·70-0·72, and the constant k possessing a value which changes with the species. This formula also accurately represents the area of the body surface in these birds, as was shown by actual measurement in a large number of cases.

3. That this relation is peculiar to warm-blooded animals and is associated with their homoiothermic character appears to follow from unpublished experiments carried out on cold-blooded animals (lizards and frogs) by Dr. Fry. His observations show that in these animals the blood volume is neither proportional to the body surface, nor to the body weight. But it varies as a power (greater than unity) of the body weight. Thus in the cold-blooded animals the percent-

age blood volume actually increases as the animal grows heavier, while in the warm-blooded animals it undergoes a steady diminution.

4. Other experiments, also carried out in association with Dr. Ray, have shown that in mammals and birds a similar proportional relation to the body surface holds throughout each species examined both for the sectional area of the aorta where it leaves the heart and for that of the trachea just above its bifurcation. It has also been found that in passing from species to species the ratio of the weight of the heart muscle to the total oxygen capacity of the circulating blood is approximately constant in a number of different species of warm-blooded animals.

5. As regards sex, it is found that the sectional area of the aorta is somewhat smaller, and the blood volume is smaller (about three per cent.) in the female than in the male animal of the same weight. During pregnancy, however, and in the puerperal state the blood volume of the female is considerably increased.

6. Under normal conditions the blood volume of mammals is very delicately adjusted. If the blood volume be altered artificially by bleeding or by transfusion the process of adjustment begins so promptly that its effect is already recognisable in an alteration of the hæmoglobin percentage when only a very small percentage of fluid has been removed or introduced, as the case may be. This fact has escaped consideration in many experiments; but it has an important bearing on conclusions drawn from observations upon hæmorrhage and transfusion.

7. The presence of excess of carbon dioxide in the air breathed quickly affects the volume of the blood, causing dilution of the plasma and an increase up to ten per cent. or more in the blood volume. This factor may be an important source of error in the interpretation of experiments carried out by respiratory methods. Amyl nitrite, which produces vascular dilatation, similarly leads to an immediate dilution of the plasma.

8. The administration of *chloral hydrate* in quantities sufficient to produce anæsthesia causes a rapid concentration of the plasma up to ten or fifteen per cent., and may thus lead to erroneous conclusions in experiments on the blood and respiration; but ether anæsthesia leaves the volume of the blood unaltered.

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2. *A Contribution to the Study of the Effect of Altitude on the Blood.* *By* Professor GEORGES DREYER *and* Dr. E. W. AINLEY WALKER.

1. In animals placed under novel conditions as regards altitude changes occur in the volume of the blood. These changes are of a regular character and follow a definite law. An analysis of the admirable series of observations on the blood volume of rabbits recorded by Abderhalden shows that the change of volume which occurs with a particular change of barometric pressure is proportional to the area of the body surface in different individuals of the given species. The blood volume of rabbits taken up from Basle (266 mètres above sea-level) and kept at St. Moritz (1,856 metres above sea-level) still conforms to our formula $B = \frac{W^{0.72}}{k}$. But k is now increased. That is to say, their blood volume is diminished by an amount exactly proportional to their body surface.

2. At the altitude of St. Moritz the hæmoglobin percentage shows an increase, and the number of red corpuscles per c.mm. undergoes a parallel increase. This change is at first entirely due to a rapidly occurring concentration of the blood. But later on it is also due in part to an increased formation of hæmoglobin (and red corpuscles), raising the total oxygen capacity of the circulating blood.

Abderhalden stated that there was no marked increase in the total hæmoglobin. But he was probably misled by his method of calculation, since the increase can be shown quite clearly from his figures. This agrees with the conclusions of Zuntz, Loewy, Müller, and Caspari. In their recent work Douglas, Haldane, Henderson, and Schneider state that at first the increase is due in part to concentration of the blood, but that the later increase is due entirely to the new formation of hæmoglobin, and that the *volume* of the blood also becomes increased. This latter statement, that the blood volume is increased in man at high

altitudes, is in disagreement with the results obtained by calculation from Abderhalden's extensive series of observations on rabbits. It is improbable that in this respect man differs so remarkably from lower animals. But the disagreement may be readily explained as due to the fallacies introduced in the experiments on man by the use of the CO method, which we have criticised elsewhere. As soon as active new formation of blood begins in the bone-marrow the errors of this method of estimating the blood volume are greatly increased.

3. After their descent from Pike's Peak, Douglas, Haldane, Henderson, and Schneider found in man at first an increase of blood volume above the normal level, followed later by a return to the normal. But our calculations from the figures found by Abderhalden for the blood volume of rabbits which were taken back from St. Moritz to Basle, show that the blood volume returned to the normal within three or four days, and was *never increased,* though the percentage of intravascular hæmoglobin did not fall to its original level until the expiration of three weeks or more. This further divergence between the results obtained on man and animals is again more probably to be attributed to the use of the CO method in the former case than to the existence of any fundamental difference between animals and man.

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3. *Natural Arrest of Hæmorrhage from a Wound. By* Dr. JOHN TAIT.

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4. *Simplified Mammalian Heart Perfusion.*
By Miss M. MACNAUGHTON *and* Dr. J. TAIT.

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5. *Contraction of Non-oxygenated Mammalian Muscle at Temperatures ranging between 0° and 40° Centigrade. By* R. J. S. McDOWALL *and* Dr. J. TAIT.

SUB-SECTION OF PSYCHOLOGY.

CHAIRMAN.—PROFESSOR J. H. MUIRHEAD.

THURSDAY, SEPTEMBER 11.

The following Papers were read :—

1. *The Theory of Psycho-physiological Parallelism: its Absurdity and Stultification as an Hypothesis. By* H. WILDON CARR, *D.Litt.*

Absurdity means that, carried to its conclusion, the theory involves the logical contradiction that the part is the whole, *quod absurdum est.*

Stultification means that adopted as an hypothesis it does not, as is supposed, leave the mind neutral in regard to all the alternatives, but by implicitly denying the possibility of unconscious psychical states it obscures the reality it seeks to elucidate.

Parallelism is a metaphysical theory of the relation of mind to body which goes beyond the facts of experience. There are three series of events: (*a*) The actions and reactions of physical things which by their influences bring about, (*b*) movements and processes in the cerebral cortex, and (*c*) consciousness or awareness of (*a*). The theory is that (*b*) alone and of itself contains the key to the interpretation of (*c*), and *vice versa* that (*c*) is always correlated with one and only one state of (*b*). Inasmuch then as (*b*) is a distinct and separable part of a whole of physical reality, and (*c*) is consciousness not of that part but of the whole from which it is separated (*a*), it follows that the part (*b*) is equivalent to the whole, which is absurd.

The theory rests on the presupposition that conscious experience is the whole of psychical existence, and that the unconscious has purely negative significance. But to assume that there can be no continuity of conscious experience by and through unconscious psychical states is unwarranted, and to suppose consciousness to be correlated with physiological activity in the cortex is to ignore the function of neural process which is simply sensori-motor, and the function of consciousness which is to throw light on eventual action.

Parallelism is not the only alternative to interaction. The relation may be a solidarity of function in which two independent realities are united. The cerebral cortex may perform the function of delaying the response of reaction to stimulus, and consciousness may be the condition of psychical experience when action is in progress. Their coincidence would then be the condition of intelligent or free action.

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2. *A New Theory of Laughter. By* W. McDougall, *M.A., M.B., F.R.S.*

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3. *Some Main Principles of Integration. By* H. J. Watt, *Ph.D.*

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4. *The Conditions of Belief in Immature Minds (Children and 'Savages'). By* Professor Carveth Read.

The conditions of belief are the same for all minds; except that (1) the relative influence of these conditions varies at different stages of development; and that (2) it is only for some minds, amongst civilised peoples, that there exists a Logic or systematic test of truth.

The ground of all belief is perception (though fallible). Further grounds or causes of belief may be distinguished into (1) the evidentiary, raising some degree of probability, such as memory, testimony; and (2) the non-evidentiary, having no logical value, such as the agreeableness of a belief, its favourableness to our desires, its connection with voluntary actions (rites or habits), or with social influences other than testimony (sympathy and antipathy, imitation and suggestion).

It is characteristic of immature minds, that the influence of illogical inferences, or imaginations, and of non-evidentiary causes of belief is relatively greater than amongst average civilised men. Imaginative beliefs, enforced by traditions, rites, ceremonies, formulæ, are in fact customs.

The possibility of forming such customary beliefs of almost purely imaginative character depends upon (1) the intensity and vividness of imaginations in immature minds, more like perceptions than ours are. (2) The absence, outside of the practical repetitive life, of any exact memories or knowledge to provide a standard with which imaginations may be compared. (3) Inability to make comparisons: (*a*) because, under the influence of desires and anxieties, the beliefs of an immature mind form relatively isolated systems; and (*b*) because,

either by imperfect development of the cortex or defect of education in thinking, such a mind is in a state of inco-ordination, which hinders comparison of ideas in the same way as disco-ordination does in hypnosis and in insane delusions.

Analysis of the reasoning implied in Magic and Animism exposes its purely imaginative character.

If action is the test of belief, it may seem at first that the beliefs of Magic and Animism are as profound as those that are based upon perception. But in our own case play-belief varies in intensity from a momentary attitude to complete absorption in dramatic illusion; and we must consider what the result will be where, as amongst savages, there is nothing to destroy the illusion. And, further, we find that that result is not really to put their superstitions upon the same footing as the necessary beliefs of practical life. For they are often mingled with deception, and involve incompatible elements; they break down under pressure of economy, social fatigue, &c.; they need the support of emotional excitement; they are often expressed by games, dances, shows, and degenerate at last into drama, epic, and fiction.

The universal prevalence of such beliefs embodied in rites and ceremonies implies some great utility; and this may be found (1) in the giving of hope and allaying of anxiety; (2) the encouragement of social co-operation; and (3) the providing of serious organised pastimes which preserve tribal tradition and develop the æsthetic aptitudes.

But scientific ideas are not to be traced to these imaginative constructions; they are derived from practical enterprises, war, industry, and commerce.

FRIDAY, SEPTEMBER 12.

Joint Meeting with Section I (Physiology).

The following Papers were read :—

1. *Some Experimental Data concerning the Localisation of Visual Images. By* Professor R. M. Ogden.

The conditions and possibilities of projecting visual images in space have been recently indicated by the experimental results of Perky,[1] Martin,[2] and Koffka,[3] and the theoretical views of G. E. Muller.[4] The experiments which form the basis of this report were performed after the publication of Mrs. Perky's paper, and were largely suggested by her work. They antedate the appearance of the other three publications.

The primary aim of the experiments was to secure visual images suggested by a series of fifty words exposed in a card-changer. Above the word was pasted a round disk of 'granite' paper, two centimetres in diameter, which the observer was instructed to fixate. As soon as an image appeared the subject reacted, and then described the nature of the image which had occurred.

There were six observers; two of them, however, performed but half the series. Thus there were 250 experiments in all, which produced 251 images.

[1] 'An Experimental Study of Imagination.' *Amer. J. of Psychol.*, 1910, xxi., 422-452.

[2] 'Die Projektionsmethode und die Lokalisation visueller und anderer Vorstellungsbilder.' *Ztsch. f. Psychol.*, 1912, lxi., 321-546.

[3] *Zur Analyse der Vorstellungen und ihrer Gesetze.* Leipzig, 1912.

[4] 'Ueber die Lokalisation der visuellen Vorstellungsbilder.' *Arch. f. d. ges. Psychol.*, 1912, xxiv., 73-76.

At times no image was reported, and at times two or three occurred in one experiment. Of the 251 images, 138 were reported as *memory*, 75 as *imaginary*, while 38 were *equivocal*. The images were all projected except in five instances for one observer, who described these as being 'in his head.' One observer placed all images upon the fixated disk. Another placed none there. The other four placed their images both on and off the disk.

The nature of the method employed made it necessary to judge the localisation of the image with reference to the disk. Thus there were four classes of localisation: (1) On the disk, (2) off the disk, but in the surrounding space, (3) at a distance, usually in the object's proper environment, and (4) in an indefinite localisation.

The correlation of the localisation with the nature of the image as memory or imaginary furnished some interesting results. The images of memory tended to be located at their proper place and distance, and the images of imagination tended strongly to be placed upon the disk. Those observers who placed few or no images upon the disk tended to locate images of imagination in the near-by space. For all who located their images variously there was a marked tendency to project the images of memory into the distance, and the images of imagination at or near the disk.

In many instances there occurred a strong tendency to locate the image upon the disk irrespective of its nature as a memory or imaginary product. In such cases a marked *inertia* of the image was manifest. This applied to both classes of image; both resisted attempts to move them from their original location. This was especially marked in the attempts to remove memory images from a distant location to the disk.

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2. *Experiments on Sound Localisation.* *By* CHARLES S. MYERS, *M.A., M.D.*

The object of these experiments, which are still in progress, is to analyse the factors determining our (notoriously uncertain) localisation of sounds situated in the median (sagittal) line of the head. A sound-proof room was used, in which the subject and the experimenter sat; six subjects, giving twenty-five sittings, were investigated. The sounds were for the most part generated outside the room, to which they were led by means of a large trumpet and a tube. In most of the experiments the sound consisted of (1) a fundamental tone of (about) 200 vibrations per second, accompanied by its first three overtones (400, 600, 800 vibrations per second); these four tones were *separately* emitted from four wind-instruments operated by an assistant. In other experiments a buzzer was used as the source of sound, situated either (2) (as before) outside, or (3) within, the sound-proof room; in a few experiments, (4) an electric bell was sounded within the room. A noiselessly-moving instrument carrying either a funnel (or, when the sound was produced within the room, the buzzer or bell), served as a perimeter to vary the position of the sound in the room. Three positions of the sound were given—directly in front of ($=0°$), directly above ($=90°$), and directly behind ($=180°$) the subject. The subject, sitting blindfold, determined the apparent direction of the sound. The position of the subject in the room was variously changed.

The subjects observed that their judgments were based on the timbre and loudness of the sounds (*e.g.*, 0° is 'the fullest, most open sound'—90° is 'a hoarse sound') and on spatial experience, including medial incidence (*e.g.* 0° 'hits me full in the face'—90° 'has a vertical feeling') and laterality (*e.g.*, 'I localise the front sounds by their being to the right'—'The back sounds affect only the left ear'). Of these, laterality was due to the sound not being given exactly in the median line of the subject's head; it was early seized on by the subjects as a criterion, but sooner or later it was of course necessarily abandoned. Medial incidence was also found to be an insecure basis. In the end, timbre and loudness proved the only reliable criteria.

Experiments were later made with the sound (1), in which the loudness of the overtones was increased or diminished, thus varying the *timbre* of the whole sound. Experiments were also made with sounds (1) and (2), in which the

loudness of the whole sound was altered. In each case, especially by the latter procedure, the number of erroneous localisations became distinctly greater. The resulting confusion was just what would be expected if timbre and loudness are the base of sound localisation in the median plane.

The importance of timbre and loudness and the unimportance of spatial (? tactual) experience were further indicated by an experiment in which a subject, after having learnt to distinguish the positions of 0° and 90°, inserted two short rubber tubes, one in each ear. The result was to alter so markedly the timbre and loudness of the sounds that he had to learn afresh their correct localisation.

These experiments suggest that the tactual impressions felt by the subject on their face and head are illusory, and that they are really of auditory origin. Just as when a sound stimulates one ear more strongly than the other it appears to hit that ear, or to be heard only in that ear, so when a medial sound stimulates the two ears equally, it appears to hit the head or to be placed somewhere in the middle line. In each case, the spatial experience is a cue leading to head movement whereby the sound is more correctly localised. It is only with the growth of experience that median sounds are given a front, top, or back position; and even then the judgments are extremely inaccurate, especially when all auxiliary information is excluded.

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3. *A Preliminary Note on Habit-formation in Guinea Pigs.* *By* Miss E. M. Smith.

The observations on which this paper was based were carried out, under the direction of Dr. Myers, at the Cambridge Psychological Laboratory, during the present year. They form part of a larger scheme designed to test the inheritability in guinea-pigs of such characters as rapidity of learning, ability to profit by practice, accuracy of performance, retentiveness, &c. With this end in view, and in the hope of discovering well-marked individual differences of behaviour, the animals were subjected to certain tests. The tests used were:—(*a*) the *labyrinth test*, and (*b*) a new form of *sensory discrimination test*, in which photic and auditory stimuli were combined. Despite the fact that this preliminary investigation was, owing to its scope, necessarily somewhat general in character, it has nevertheless brought to light several hitherto unrecorded points of interest concerning guinea-pig behaviour.

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4. *The Relative Fertility and Morbidity of Defective and Normal Stocks.* *By* F. C. Shrubsall, *M.D.*

Observations have been made on the family history of children presenting some degree of educable mental deficiency and also of children who have gained scholarships. The chief points noted were the size of the fraternity, the order in the fraternity of the child under observation, and the number of members of the fraternity who had died by the time the individual round whom the record centred had reached the age of nine.

Correlation between order in fraternity and size of fraternity:—

Type	No. Observed	Order in Fraternity	σ	Size of Fraternity	σ	r
Defective . .	1,000	4·35	3·24	6·32	3·27	·81 ± ·06
Normal . .	1,000	2·87	2·16	4·79	2·55	·65 ± ·008

The chief deterrent factors are that no records of childless families are possible, and that the smaller families were not perhaps complete, although in over 80 per cent. of cases this was the case.

Correlation between the size of the fraternity and the number of members who had died :—

Type	No. Observed	Size of Fraternity	σ	Number Dead	σ	r
Defective . .	1,000	6·46	3·35	1·91	2·15	$\cdot 7 \pm \cdot 01$
Normal . .	3,000	4·59	2·48	0·48	0·89	$\cdot 5 \pm \cdot 009$

This gives an average net family of 4·55 for the defective and 4·11 for the normal, but by the time the central child has reached adult age the disparity would probably have disappeared.

From a study of 700 families it appeared that on an average 1·43 children were mentally defective in a fraternity of the average size of 6·05. The known number of defective members in each family was, however, much higher, being :—

No. Affected	No. of Families	No. Affected	No. of Families
1	367	6	10
2	148	7	6
3	79	8	5
4	49	9	2
5	32	10	1
		11	1

The fact of mental deficiency was found to have been noted :—

In infancy in	61	per cent. of cases
By the age of four	7	per cent. of cases
By the age of five	2·5	per cent. of cases
On going to school	28·5	per cent. of cases

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5. *The Relation between Habit and Memory.* *By* Miss May Smith.

This paper dealt with

1. Bergson's two forms of memory which he considers to be fundamentally distinct.
2. Experiments illustrative of (*a*) pure memory; (*b*) habit interpreted by memory. If the two forms are distinct, then tests belonging to each group should show high correlation with the others of the same group, but low correlation with those of the other group.
3. The results of the experiments worked out according to the method of correlation.
4. General considerations.

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6. *On Changes in the Spatial Threshold during a Sitting, and on the Nature of Thresholds in General.* *By* Godfrey H. Thomson.

The writer has previously[1] suggested that during a sitting of one hundred judgments the spatial threshold is frequently higher at the beginning than in

[1] *Brit. Journ. Psychol.* 1912, v. 233.

the middle, and that later it rises again. Experiments have been carried out to test this with the following results :—

TABLE I.

Average Changes in the Spatial Threshold on Right Forearm during the Progress of a Sitting.

	Subject No. 6			Subject No. 7			Subject No. 8	Subject No. 9	Weighted Mean
Progress of Sitting	cms.	cms.	cms.	cms.	cms.	cms.	cms.	cms.	cms.
i	2·98	2·15	3·25	3·30	3·28	3·99	4·50	3·50	3·38
ii	2·66	1·95	3·11	2·95	2·28	3·29	4·57	3·20	3·05
iii	2·40	1·85	3·08	3·25	2·68	3·34	4·42	2·60	2·97
iv	2·16	2·19	2·58	3·05	3·28	2·99	4·17	2·45	2·83
v	1·84	1·59	3·16	3·40	3·28	2·84	4·80	2·85	2·95
vi	2·01	1·72	2·29	2·95	3·08	3·09	3·97	2·95	2·74
vii	1·95	2·05	2·61	3·35	3·68	3·59	4·95	3·20	3·14
viii	2·06	2·05	3·06	2·45	3·88	3·34	4·12	3·05	2·94
ix	2·52	1·92	2·68	3·05	3·68	3·44	3·75	3·15	2·98
x	2·06	1·85	2·15	2·65	3·28	3·44	4·45	3·05	2·84

Each of these columns is based on ten sittings, each of 100 judgments and lasting about twelve minutes, except column 5 based on five sittings only. Each sitting is divided into ten periods, shown by Roman numerals. The first figure, for example, 2.98 cms., is calculated from 100 judgments—namely, the first ten judgments at each of ten sittings. For subject 6 only, the sitting proper was preceded by a preliminary group of ten judgments. With this subject the Method of Non-Consecutive Groups [2] was used, and the results were calculated by Urban's formula.[3] The method used in the other cases would be defined, in the nomenclature suggested by the writer,[4] as the Method of Right and Wrong Cases with catches, using the direct Limiting Process of calculation.

The results suggest that often the threshold falls sharply during the first twenty judgments and then slowly up to about forty judgments, after which it becomes erratic, but often falls again at the very end of the sitting. The practical advice would be to give preliminary judgments and not to prolong the sitting. Space does not permit a discussion of whether these results are 'significant' or due to chance sampling, but this will be done elsewhere.

Each of the numbers given above is itself an average, and the variation is much greater than they indicate. Whether we look upon this variation as due to experimental error, or as a true variation [5] depends upon our point of view. There is no essential difference.

TABLE II.

Spatial Threshold on Right Forearm. Subject No. 6. Method of Non-consecutive Groups.

Stimulus value in Cms.	0	0·5	1	1·5	2	2·5	3	3·5	4	4·5	5
No. of answers *two*	52	6	8	21	56	84	105	125	141	144	148
Total No. of Judgments	1500	150	150	150	150	150	150	150	150	150	150

An average threshold is a matter of mathematical definition, not of psychological experience. It has been defined as the point where 50 per cent. of correct

[2] Thomson, *Brit. Journ. Psychol.* 1912, v. 204, 214.
[3] *Archiv. f. d. ges. Psychol.* 1909, xv. 291, 307.
[4] *Op. cit.* 204, 210, 240.
[5] *Cf.* Brown, *Mental Measurement,* Camb. 1911, 20 footnote (references to Müller, Fechner, Bruns) and 84.

answers are given; and again as the 80 per cent. point; and 20 per cent., or any per cent. might be chosen. Especially is it misleading to say that stimuli below the average threshold cannot be distinguished from one another. On any one occasion anything may happen, but when a number of judgments are made the result as in Table 2 *indicates differences between all the stimulus values used.* Similar records exist for many thresholds, in particular for the difference threshold for lifted weights.[6] Those therefore who, like Poincaré,[7] say that weights which differ by less than the 'difference threshold' produce identical sensations, are wrong, and the arguments based on this statement are incorrect.

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7. *A Simple Method of demonstrating Weber's Law and its Limitations. By* SHEPHERD DAWSON, *M.A., B.Sc.*

The main facts of Weber's Law with its limitations can be demonstrated easily and quickly in the following manner:—

Along a radius of a disc of white paper pierce a number of circular holes of equal diameter. Punch equal and similarly placed holes in other discs of grey paper of various intensities. Rotate one of these discs in front of a box lined with black velvet, and a series of dark rings will be formed on the disc which differ progressively in brightness, the innermost being the darkest. The size of the holes should be such that the smallest ring can be easily seen while the largest is indistinguishable: holes from three to four millimètres in diameter and about 1·5 cms. apart on a disc 13 cms. in diameter give satisfactory results.

If no light be reflected through the holes in the disc, then the ratios of the intensities of the rings to the intensity of the disc depend only on the diameter of the holes and the distances from the centre. Hence, if all the discs be similarly cut and Weber's Law be true for brightnesses, the same number of rings should be distinguishable on each disc. To demonstrate the law we have, therefore, only to rotate the disc and count the number of rings that can be seen.

As the intensities of the grey papers can be found by matching them with mixtures of black and a standard white, and as the ratio of the intensity of each ring to the intensity of the background can be found by measuring the diameter of the hole and its distance from the centre, it is possible to state the results numerically in terms of thresholds of discrimination and to show to what extent Weber's Law is valid.

8. *Some Experiments on Recovery from Fatigue. By* MISS MAY SMITH.

1. The aim of this set of experiments.
2. Description of the apparatus and details of the experiments.
3. Results:—
   - (*a*) Average errors for each week and consideration of the kinds of errors.
   - (*b*) The effect of fatigue induced by three nights with very little sleep.
   - (*c*) The return to normal.
   - (*d*) A comparison of subjective and objective records.

4 Some general conclusions from these experiments.

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9. *A Comparative Investigation of Fatigue Tests. By* J. H. WIMMS.

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[6] v. Urban, *op. cit.*, and especially Fernberger, *Psychol. Monographs*, 1913, xiv. (4), 54, 64, where much smaller steps are used.

[7] *Science and Hypothesis*, Scott, 1905, 22.

MONDAY, SEPTEMBER 15.

Joint Meeting with Section L.—See p. 744.

TUESDAY, SEPTEMBER 16.

The following Papers were read :—

1. *Application of the Binet-Simon Intelligence Scale to Normal Children in Scotland. By* J. L. McIntyre, *D.Sc., and* Agnes L. Rogers, *M.A.*

This paper gave the results of a series of experiments in the demonstration school attached to the training centre in Aberdeen. The general aim was to study the application of the scale, its value in the discrimination of backward from normal children, and its suitability, in the case of Scottish children, for determining the degree of backwardness or ability in the individual child. The 1908 scale was used, but account was also taken of the modifications introduced by the 1911 scale, and our data were correlated with those of Goddard in America and others.

The general result supports the now familiar criticism that the tests are too easy for the earlier and too hard for the later years. Fairly satisfactory for five, eight, nine, and ten, they are quite unsuitable, for various reasons, at four, twelve, and thirteen, and poor at the other ages. Some of the tests would require, for our conditions, to be set back or advanced from one to three and even four years.

The tests in which the northern children conspicuously failed, at the required age, are in the main those which may be said to appeal to 'natural intelligence,' alertness, adaptability, &c., while those in which they show precocity are mainly those which bring into play habit, training, and memory. This unexpected result requires further investigation. In general, the distribution of abilities—average, exceptionally low and exceptionally high—is similar to that found for American, French, and English children. The gifted are 11 per cent., the backward 18 per cent. of the whole, and there are more exceptional (gifted or backward) boys than girls. In comparing our ranking of the children by these tests with that of the teachers, great diversity was found in some classes, close agreement in others; the indices of correlation range from 0·85 to 0.16, the majority being about 0.5.

2. *Tests of Reasoning and their relation to General Mental Ability. By* Robert C. Moore, *M.Sc.*

The object of the research was to demonstrate the close relation between intelligence and the results of tests involving processes of reasoning or its essential elements. An earlier research, carried out at Liverpool and reported to this Association, had given indications of the closeness of this relationship. But, as was inevitable in a preliminary research, the data were admittedly inadequate and furnished suggestions rather than proofs.

The present research differed from the former in several important respects. A few tests involving relatively simple processes, such as Bisection of Lines, Cutaneous Discrimination, were retained, but a far larger number of more complex tests were added. Many of these, such as Irregular Dotting, Card Dealing, did not involve reasoning. Others involved mental processes essential to reasoning. These, as far as possible, were so chosen as to be representative of different orders of complexity. Thus, the Opposites test involved the comprehension of a definite kind of logical relation between terms; the Analogies or Mixed Relations involved the comprehension of relations between relations; the Correction of Reasons (modified from Bonser) involved judgment about a definite kind of relation; the Completion of Syllogisms (modified from Burt) involved the inference of one judgment from other judgments; the Completion

of an Argument (modified from Ebbinghaus) involved the comprehension of a series of inferences.

Further tests were added, dealing with non-reasoning elements in the reasoning tests, such as reading, writing, and free association.

In all twenty-five tests were used for the main group and were marked variously for speed, accuracy, and amount. Introspections were obtained from children and trained adults to determine how far the tests actually involved the mental processes they were designed to represent; and the conclusions were further checked by experimental variations in the procedure and material.

A larger number of children were tested than in the former investigation, viz., in the main group, sixty-five boys and thirty-one girls. The children belonged to the same form, and the age range was one year instead of two. The calculations for the boys and girls were kept apart. With the help of other investigators the more important tests were further applied to groups of different social status and of various ages.

The results obtained from the various groups are consistent. In the main research the reliability coefficients, with few exceptions, range from ·70 to ·88. The correlations with intelligence for the better attested tests of reasoning (Opposites, Analogies, Syllogisms, Argument) provide the highest correlations, ranging from ·47 to ·74. Considering the number and size of the groups and the reliability of the tests and of masters' estimates of intelligence, these correlations seem to be as satisfactory as any yet obtained.

On drawing up hierarchies and employing the method of multiple correlation and other criteria it seems clear that the correlations are determined chiefly by the presence of elements essential to reasoning. On eliminating the influence of reading and writing by means of the appropriate formulæ, the correlations with intelligence remain, in the case of the more complex reasoning tests, but little changed. On correlating the size of the intelligence coefficients for the several tests with the degree to which (according to the children's own introspections) reasoning entered into the performances, the coefficient is found to be ·89.

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3. *Additional Reasoning Tests suitable for the Mental Diagnosis of School Children. By* W. H. WINCH, *M.A.*

The following set of tests is offered as additional to those presented to the British Psychological Society on May 6, 1911:—

I.—Value and Uses of the Tests.

They are believed to be of service, because,—

(1) They help us to measure what are usually called the 'higher mental functions.'

(2) Psychological tests of these functions are at present very few in number, and have not been 'standardised' by usage.

(3) They, with other similar tests, help Psychology to meet the complaint of the educationist that our science measures only the trivial units of mental work involved in elementary sensory and motor functions.

(4) They are completely *extra-scolaire*, that is, are not taught in schools, and are therefore a good measure of the natural ability of the pupil as distinguished from the pedagogical proficiency of the school.

(5) Whilst they are too difficult to adequately measure 'Mental Deficiency,' they serve excellently well to indicate 'Subnormality,' or what is usually known as 'Backwardness.'

(6) They will help teachers to grade their pupils on a basis of natural ability.

(7) With other similar tests, they will enable us to measure the 'transfer' effects (if any) of so-called rational studies, like Euclid (Demonstrative Geometry), Grammar, and Problematic Arithmetic.

(8) They may enable us to discover the mental differences (if any) between boys and girls of school age in an important mental function.

(9) They will help us to select 'Scholarship Children' without our selection

being prejudiced by the pedagogical proficiency of the school which the pupil attends.

(10) They help us to distinguish the different levels of mental ability of pupils to be found in schools of different 'social class.'

II.—The Tests and Method of Administration.

The tests, one at a time, are presented in writing to the children, are read twice, without undue emphasis, by a person whose voice and accent are familiar to the children, and are then answered in writing, one at a time. They are of service between the ages of eight and fifteen. One set of tests, distinguished as Set 5, follows:—

(1) Mary sowed some seeds in some flower-pots, and every few days she watered them. Johnny said that he did not see that putting water on the seeds did any good. Do you think that Mary could prove to him that watering them made them come up quicker, or do you not? If you think she could, say how you think she could do it. If you think she could not, say why not.

(2) Do you think a shilling is larger than a halfpenny, or smaller than a halfpenny, or the same size? Suppose you had a halfpenny and a shilling and nothing else to measure with, how could you find out?

(3) Harry and Tom live in a long road a long way away from each other. Harry starts from his house to go to meet Tom, and Tom starts from his house to go to meet Harry. They both start at exactly the same time, but Tom walks faster than Harry. Do you think they will meet nearer Tom's house or nearer Harry's house, or exactly in the middle? You must give a reason for your answer.

(4) If more than half the boys in a class get all their sums right, and more than half the boys in the same class get no mistakes in dictation, do you think there were any boys who got all their sums right and also no mistakes in dictation, or do you think there were no boys who got all their sums right and also no mistakes in dictation, or can't you tell? You must say why.

III.—The Marking of the Tests.

They are marked simply 'right' or 'wrong,' not on any *à priori* scheme; for the method of marking emerges quite simply from a consideration of the papers worked by the children. Illustrative papers will be read from boys and girls of various ages, of various grades of mental proficiency, and of various 'types' of school.

The first problem, based on the logical method of difference, is not marked correct unless this method is appealed to.

The second problem is based on the Geometrical Method of Superposition, and is marked correct if the examinee states that he would place one on or over the other. The examinee is not marked wrong if he says the shilling is larger. The first part of the question only introduces the real problem.

The third problem depends on the Dynamical Principle that, in equal times, the boy moving faster goes further. The answer is correct which places the meeting of Tom and Harry nearer Harry's house than Tom's, and gives the reason.

The fourth problem is based on the Overlapping of Classes within a Whole, reminiscent of Euler's diagrams in Logic. The examinee, to be marked correct, must perceive that the classes overlap, and give a reason.

IV.—The Results of the Tests.

Figures were given to show:—

(1) That the results of the tests correlate fairly well with age.

(2) That the results correlate much more closely with mental proficiency as indicated by school 'standards' or 'grades' than with age.

(3) That there is a considerable difference in 'reasoning ability' in schools attended by children of different 'social classes.'

(4) That the difference between boys and girls in non-numerical reasoning

appears small and doubtful, the balance of advantage inclining towards the boys.

(5) That the pedagogical proficiency of the schools has but slight and indirect bearing upon the results of tests like these.

4. *Analysis of the Mental Processes involved in Spelling.* *By* Miss S. S. FAIRHURST.

'Spelling' means two things; (*a*) The fact that a certain word is 'correctly' and usually represented by certain letters, the dictionary spelling. This fact is objective to any given speller. (*b*) The actual psychical processes involved in reacting to a certain stimulus by reproducing the constituent letters of a word-whole in speech or writing. Spelling in this sense is largely a matter of acquired habit.

Imaginal type and spelling efficiency.—There is no direct relation between these two characteristics. The determinant of efficiency is some factor working within imaginal type.

Visual and speech factors.—It is probable that the relative importance of these cannot be determined quantitatively, because of the difficulty of isolation. Presentation of material by sight or articulation alone does not isolate, because of the presence of supplementary imagery. Verbal imagery tends more to heterogeneity than concrete. The difficulty of control, of suppression of any particular form at will, is very great. Not only do observers find difficulty in suppressing their own preferred type of imagery, but observers generally find greater trouble in suppressing vocalisation than visualisation—the tendency to articulate on seeing a word is irresistible, and appears to be essential to the apprehension of the visual form. The *unit* of spelling is usually the syllable, which finds direct expression as such, and is treated as a whole. Syllabic grouping of letters is primarily a matter of articulation—the syllable is a speech-whole. Grouping extends frequently to the visual form—'the letters seem to be in blocks.' There is also visual synthesis apart from syllabic grouping.

'*Imageless*' *spelling.*—This may occur in two ways: (*a*) In which the word is so familiar as to be spelt immediately and almost unconsciously. (*b*) In which it is a case of 'imageless' knowledge of the facts of spelling. There is the distinction between knowledge of the facts of spelling, and mere reference to imagery, both in learning and in recall. With the imageless observer the process is one of acquiring and referring to knowledge of facts about the spelling, whether directly or by mnemonics. Whatever the general term 'imageless' may ultimately turn out to be under more delicate analysis, the distinction is a real one; and the problem of the imageless thinker, hitherto neglected as regards the spelling memory, exists here as elsewhere.

The writing-motor element.—In the total word-complex, this element appears to have a value different from and less important (for adults) than that of the speech-movement. There is never a tendency to write a word on hearing it, comparable in intensity to the impulse to pronounce it on seeing it. If the impulse is present it is always completely controllable. In learning by writing, the articulatory element is pressed into service also as a rule. The actual value of the writing-motor element is obscured by the adventitious aids to attention, to the visual memory, and to the fusion of visual and auditory elements that it affords. In the recall of a word, observers can rarely detect any qualitative difference due to whether the word was written or not in learning. If such qualification occurs, it is usually incidental merely—the writing-motor element pure and simple has not been found to act as the conscious medium of memory, as the articulatory elements may act. It is more subordinate to the visual memory than the latter.

5. *The Conditions which arouse Mental Imagery in Thought.* *By* CHARLES FOX, *M.A.*

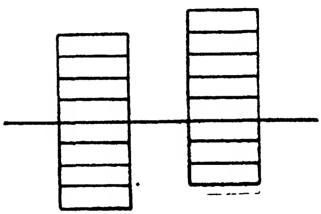
Certain selected propositions of varying orders of difficulty were dictated to fifteen adult subjects, who were instructed to give a full account of what they could observe in their consciousness during the process of realisation of the meaning of the propositions. The instructions were directed mainly to the

investigation of the contents of consciousness is imageless thought. The propositions were concerned with mathematical, grammatical, historical, and other conceptions, and the subjects were given sufficient time to make a full record. The results of their introspection, concerned with 178 acts of thinking, were subsequently analysed and classified, and were found to yield quite clearly the chief conditions which favour or hinder the development of mental images in the higher thought processes.

It seems probable from these results that, under ordinary conditions of thinking, mental images would be absent in about 50 per cent. of all cases.

Vivid mental imagery may hinder or aid the act of thinking, depending on whether the image itself or its meaning occupies the focus of consciousness. When the meaning of a proposition is readily understood or when it is quite familiar, there seems to be no tendency to embody the thought in an image. Thought is carried on in these cases entirely by meanings. In many cases the consciousness of meaning precedes the full utterance of the statement—the initial words carry the whole meaning in themselves.

The conditions for producing images are easily seen from the following case of introspection. Two of the propositions given were (α) if unequals are added to unequals the wholes are unequal; (β) if equals are added to equals the wholes are equal. These were dictated in the order given, with an interval between. With reference to the former one of the subjects said 'Doesn't sound probable somehow. Rather a wrench necessary to enable me to realise that you have two sets of things to work with. Then I saw that it is a lie (*sic*), as a picture of heaps of plain wooden bricks arose, thus:'



With reference to the second statement he said 'Sounds much more reasonable. Of course it's true. No need to fetch the bricks out to prove that one.' And indeed he had no mental image. This striking case is but a clear instance of what seems to be general.

For the experiments show that any kind of struggle or delay in consciousness is a favourable condition for arousing a mental image. Conflict or disagreement, any attempt to overcome a difficulty of understanding, suspension of judgment, doubt, emphasis, all tended to produce mental images in abundance. And all of these are instances of struggle or delay.

The experiments also showed that the contrary set of conditions are unfavourable to the production of images. Thorough or immediate understanding, an easily grasped conception, ready assent, straightforward or unimpeded reasoning, were all cases in which images, as a rule, played no part. Whatever promotes the easy or unimpeded flow of thought is unfavourable to the production of mental imagery and *vice versâ*. Just as an electric current has to meet a high resistance before it produces light, so thought has to encounter an obstacle in order to evoke an image.

6. *The Psychological Foundation of Economics. By* Rev. P. H. Wicksteed, *M.A.*

7. *Psycho-analysis. By* William Brown, *D.Sc.*

In the course of this paper the following topics were discussed:—

1. Freud's fundamental views on the nature of consciousness, the preconscious and the unconscious, as set out in the final chapter of the 'Traumdeutung.'

2. The technique of psycho-analysis and its relation to hypnotism as means of overcoming repressions.

3. A comparison of the views of Pierre Janet, Sigmund Freud, and C. G. Jung on the nature of the psycho-neuroses.

4. Brief report of a case of an extensive amnesia of long standing cured by psycho-analysis and hypnotism.

8. *The Analysis of some Personal Dreams, with reference to Current Theories of Dream-Interpretation. By* T. H. PEAR, *B.Sc.*

This Paper dealt with the following matters :—

Freud's theory of the dream mechanism.

The censorship of consciousness, mental conflicts, repression, the unconscious.

The 'manifest content' and the 'latent content' of dreams.

The dream-work. The processes of distortion and disguise. Condensation, symbolism, dramatisation, displacement of interest and emotion, superficial association, the play on words.

The 'wish theory' of dreams. The relation between the conscious and the unconscious wishes. Objections to the theory. Alternative explanations of the dream, and their relation to Freud's theory.

An account of some personal dreams. The dream matter traced back to the memories which formed its raw material. Illustrations, in these dreams, of the above processes of the dream-work. The 'meaning' of these dreams. Is Freud's theory adequate for their explanation? Other possible explanations of them.

The process of psycho-analysis applied to the dreams. Criticisms of this method. Objections to the method of 'free association.' The determination of the course of association. The investigation of dreams by the dreamer himself, and by others.

9. *The Relation of the Emotions to Motor Discharge. By* Professor G. J. STOKES, *M.A.*

WEDNESDAY, SEPTEMBER 17.

The following Papers were read :—

1. *Colour Perception and Preferences of an Infant at Three Months. By* C. W. VALENTINE, *M.A.*

Previous investigators have tested the colour preference of infants by noting the colours which they most frequently seize. By this method, however, one cannot test a child before it is about six months old. A series of experiments, spread over about four weeks, was carried out with an infant, commencing at the age of three months, by a new and simple method, viz.. measuring the times during which the child looked at either of two coloured wools held before him for two minutes at a time. Nine colours were used; each colour was presented with each of the others, and the scores of each were added together. Very decided preferences were discovered, the order of preference being as follows, starting with the most pleasing :

$$\text{Yellow} \begin{cases}\text{White, Red}\\ \text{Pink}\end{cases} \begin{cases}\text{Brown}\\ \text{Black}\end{cases} \begin{cases}\text{Green, Violet}\\ \text{Blue}\end{cases}$$

The brightest colours were obviously liked best, but neither brightness nor novelty can explain the order of preference among Red, Green, Blue, and Violet, which were equally bright. It is suggested that colours are preferred at this early age, according to their power of stimulating the organism; *cf.* the results of Féré, who found that muscular strength was stimulated most by colours at the warm end of the spectrum and least by colours at the cold end.

That different colours were actually perceived is inferred from the striking difference between the scores for Red and Green (or Blue), and between the scores for Green (or Blue) and Violet, though these were equally bright.

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2. *Modern Experimental Investigation of Testimony.* *By* T. H. PEAR, *B.Sc.*

Previous experimental investigations.

Two points which have not yet been settled, and about which great differences of opinion exist in current psychological and legal literature :—

(1) Is the unreliability of the testimony of normal children as great as previous writers have believed? If so, what factors affect this circumstance?

(2) How great is the reliability of the testimony of the mentally defective child? Does it differ qualitatively as well as quantitatively from that of the normal child?

Legal significance of these questions.

The 'event' test and the 'picture' test; their relative advantages.

Description of the present experiments. Combination of the advantages of both the above tests. The *same* test applied to both normal and mentally defective children of the same ages (11 to 14 years), and of both sexes. Relatively large number of subjects; 65 normal and 78 mental defectives.

The pre-arranged event. Reasons for selection of interval between event and first testimony (20 hours), and second testimony (seven weeks).

The 'narrative' (Bericht), and the 'interrogatory' (Verhor). Their effect on the reports given.

Points of special psychological interest in connection with the reports, *e.g.*, testimony for colours, estimation of time, size, distribution of interest, effect of past experience. Suggestibility of the two classes of children qualitatively and quantitatively indicated.

Reconstruction of the event from the majority of replies given in each school. The relation of this 'reconstructed event' to the actual occurrence.

Estimation of the value of the evidence of the normal and of the mentally defective. Individual differences in both classes. Comparison of the classes.

The question of sex differences.

Correlation between the capacity to give reliable testimony and general intelligence.

Correlation between total number of items reported by any individual and their reliability.

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3. *The Testimony of Normal and Mentally Defective Children.* *By* STANLEY WYATT.

A. 'Narrative.'

1. *Range and Accuracy.*

The number of items correct and incorrect was determined for each of the groups tested. A remarkably high degree of accuracy was found to exist in every case, hence in this respect the children's evidence is exceedingly reliable. The length of the descriptions given by the mentally defective children was appreciably less than that of the normal children. Individual differences were well marked throughout.

2. *Classification into Categories.*

The results were arranged in categories of colours, shapes, sizes, positions, actions, sequence, and items (these included 'personal items' such as articles of dress and personal features, in addition to items not directly associated with the lady and gentleman who carried out the event). Such a classification disclosed a very unequal distribution of interest in the various components of the event. The Narrative chiefly consisted of a description of actions, items, and positions; the accounts of the other categories were relatively insignificant.

B. 'Interrogatory.'

1. *Number of Correct and Incorrect Replies.*

Over one-third of the replies of the normal children and over one-half of those of the defective children are incorrect. A repetition of the questions after an interval of seven weeks causes a slight decrease in the accuracy of the Interrogatory.

2. *Classification into Categories.*

The questions which refer to the categories of actions and items are answered most frequently. The evidence in connection with colours and the sequence of events is very unreliable. Whenever there is any uncertainty about the existence of an object, the uncertainty is accentuated in the responses to the questions about its colour. In all the categories the replies of the defective children are much less accurate than those of the normal children.

3. *Suggestibility of the Children.*

Generally, the children are suggestible; the defective children to a much greater extent than the normal children. The suggestibility increases as the interval between the event and recall becomes greater. Knowledge of past experiences of similar situations has a considerable influence upon the replies given. Components of the event which are vaguely perceived, or not perceived at all, are often interpreted or supplied according to the manner in which they are most usually experienced.

There appears to be no correlation between general intelligence and susceptibility to suggestion, but the older children are less suggestible than the younger. The relative suggestive force of the questions is approximately the same for each of the groups tested.

The most suggestive questions are those which refer to the less important or obscure features of the event, and especially to those suggested components which might be expected to exist. On the other hand, those questions are least suggestive which refer to the most prominent, uncommon, or irrelevant components of the event.

4. *Estimation of Sizes and Time.*

The normal children are usually fairly accurate in their estimations of the dimensions of objects; the defective children fail completely in this respect.

In every case, the duration of the event was over-estimated by the normal children, and there appears to be a definite connection between the number of details observed by any child and the amount of his over-estimation.

The defective children have no conception of the length of such a time interval.

C. General Conclusions.

1. Normal children, when allowed to volunteer their evidence under favourable conditions, and when uninfluenced by factors such as cross-examination, the personality of the questioner, &c., can give testimony of a high degree of accuracy, but of small range.

2. The testimony of the normal children is distinctly superior, both quantitatively and qualitatively, to that of the mentally defective children.

4. *Contrast as a Factor in Psychological Explanation.* *By* Dr. W. G. Smith.

Section K.—BOTANY.

President of the Section.—Miss Ethel Sargant, F.L.S.

THURSDAY, SEPTEMBER 11.

The President delivered the following Address:—

We were welcomed to Birmingham last night, and now—made free of the city—we assemble this morning to justify our position as its guests. But, before entering on the work of the Section your President is authorised, and even required by custom, to glance at the events of the past year in the botanical world.

My predecessor in this chair had a great loss to record in the death of Sir Joseph Hooker, the *doyen* of British botanists, and a familiar figure at so many meetings of this Association, where we were proud to feel that he belonged to our Section. This year we have no peculiar grief, but we join with the whole Association in lamenting the death of Lord Avebury. We have some right to offer a special tribute to his memory, since several of his published works were on botanical subjects. His book on the 'Fertilisation of Flowers' in the 'Nature Series' opened a new world to many non-botanical readers, and there are probably others here besides myself who have reason to be grateful to him for that charming introduction to field botany, and for the companion volume on 'Flowers, Fruits, and Leaves.' The great mass of first-hand information on the external characters of seedlings, contained in two massive volumes under the modest title of 'A Contribution to our Knowledge of Seedlings,' was collected under his direction and put together by himself. It is not only a book of reference to students of vegetable embryology, but no doubt played its part in reviving interest in that important subject. The work which he published was, however, the least part of Lord Avebury's contribution to Natural History. He represented a small but most distinguished class of naturalists, amateurs in the best sense of the word, since they work for pure love of the subject. Whether they happen to be men of affairs in great positions, like Lord Avebury, or artisans devoting their Saturday afternoons to original research in Natural History, they are the salt of the subject, preserving it from the worst effects of a purely professional and academic standard.

There is one more event of the past year to be mentioned before entering on the professional portion of this Address. Section K has made a great innovation in choosing a woman for its President this year, and I will not refrain from thanking you in the name of my sex because I happen to be the woman chosen. And, though I must and do feel very keenly the honour you have done me as a botanist in electing me to this position, yet that feeling is less prominent than gratitude for the generosity shown to all women in that choice. Speaking in their name, I may venture to say that the highest form of generosity is that which dares to do an act of justice in the face of custom and prejudice.

The main subject of my Address this morning is the Development of Botanical Embryology since 1870.

Botanists, as well as zoologists, have used the term Embryology in two senses. Balfour's remarks apply to both sciences :—

'Strictly interpreted according to the meaning of the word, it ought to deal with the growth and structure of organisms during their development within the egg-membranes, before they are capable of leading an independent existence. Modern investigators have, however, shown that such a limitation of the science would have a purely artificial character, and the term Embryology is now employed to cover the anatomy and physiology of the organism during the whole period included between its first coming into being and its attainment of the adult state.'

The older botanists used the term in the narrower sense. They included the study of the embryo-sac and the structures contained in it before the formation of the unfertilised egg-cell, as well as the fertilisation of the latter and its subsequent divisions. But they did not proceed beyond the resting-stage of the embryo within the ripe seed. Here, as in zoology, this division is arbitrary and inconvenient. Accordingly, in the following remarks on the Embryology of Angiosperms, I include every stage in the development of the plant, from the first division of the fertilised egg-cell to maturity.

Systematists, from Caesalpino onwards, have paid much attention to the structure of the seed, and their observations are the earliest we possess on botanical embryology. They were, indeed, forced to study the embryo because its characters are often of systematic importance. The number of cotyledons, for instance, is the most constant character which separates the two great classes of Angiosperms. Again, the endosperm is not part of the embryo, but its presence or absence in the ripe seed—so important systematically—determines the function of the cotyledons after germination, and thus influences their structure profoundly. In this way botanists became familiar with the structure of the embryo in the ripe seed before they had traced its origin from the fertilised egg-cell or followed its development after germination.

The early history of the embryo was a sealed book to observers without the help of the compound microscope. Accordingly we find that work on the external morphology of seedlings preceded that on the formation of the embryo. For the description of seedlings we must go back to the middle of last century. The greatest name in this school is that of Thilo Irmisch (1815–79). His work, like that of earlier observers in the same field, was neglected by the succeeding generation owing to the rapid development of microscopic botany. For a time the study of anatomy eclipsed that of external morphology.

The earliest observers to study the embryo-sac of Angiosperms with the help of the compound microscope were naturally attracted by the history of the ovum and the process of fertilisation. Little progress was made in this direction, however, owing to the imperfect technique of the day. The divisions of the fertilised egg-cell are more easily followed, as Hanstein showed in 1870. His classical paper is the foundation of botanical embryology in the narrower sense—that is, of the study of the embryo from origin to germination.

This period in the plant's history would seem, indeed, very well defined. It begins with the first division of the fertilised egg-cell—undoubtedly a natural epoch, for a new generation dates from it. It ends with the formation of the ripe seed, which is a true physiological epoch, since it corresponds with a complete change in the conditions of life. We have seen also that the morphologists who have dealt with the immature plant have fallen naturally into two groups, one ending and the other beginning their work at this very point.

Experience, however, has shown here, as in zoology, that embryologists lose more than they gain by this division of their subject. It is, indeed, neither so simple nor so natural as it appears at first sight.

It is not simple because the embryo is not always completely dormant during the interval between the formation of the ripe seed and the first steps in germination. On the contrary, in a large proportion of Monocotyledons, and in a smaller but still considerable proportion of Dicotyledons, the embryo is an almost undifferentiated mass of meristem when the seed first ripens. It becomes differentiated internally and externally by degrees during the long interval before germination. This is sometimes called the maturation of the seed, and

it is quite distinct from its ripening. Maturation is a process characteristic of the seeds of geophilous plants, which commonly lie in the ground for a year at least before germination.

In such cases the period of rest occurs immediately after the seed is ripe, and while the embryo is still undifferentiated. But the embryo is not comparable morphologically to that in the seed of an annual, for example, which may have ripened at the same time. The embryo of an annual has root, stem, and leaves, besides its cotyledons, and is ready to germinate immediately on the return of spring.

The morphologist, then, must continue the study of his geophilous embryo throughout the period of maturation if he is to compare it with that of the annual. Even then he will find it less advanced than the annual embryo, though both be examined as they break out of the seed. For the geophyte may perhaps be four or five years before it flowers, while the annual has to complete its whole life-cycle in a single season.

Nor is the division of the subject into two parts, the first ending with the embryo in the ripe seed, a natural one, even if the time of maturation be included in that first period. The structure of the embryo cannot be completely grasped by reference to its past only. The observer must expect adaptive characters of three kinds : first, those imposed upon the embryo in the past by its development within the embryo-sac while it is still parasitic on the parent plant; secondly, certain adaptations to the process of germination itself; and, finally, characters which will be useful after germination. Before the utility of the characters included in this third class can be fully understood, the development of the seedling must be followed for some time. In short, the structure of the embryo is dependent on its future, as well as on its past; and a division of the subject which excludes that future is, as Balfour says, purely artificial. Thus the work done of late years on the anatomy of the seedling has not only completed Irmisch's work on its external morphology, but has also thrown light on the problems of early embryology attacked by Hanstein and his immediate followers.

These problems are of two kinds, relating to the internal anatomy or the external morphology of the embryo. Hanstein himself was chiefly interested in the former. It is curious to realise when reading his paper that up to the date of its publication botanists were prepared to find an apical cell in the embryo of Angiosperms. They acknowledged, indeed, that no such cell existed in the growing-points of the mature plant.[1] There each new portion of tissue was formed by the activity of a group of similar and equivalent cells. But it still seemed possible that the embryo might possess an apical cell in the earlier stages of its growth—a reminiscence of its Cryptogamic ancestors. Hanstein's work disposed once for all of this possibility. It was conclusive even against the great authority of Hofmeister, who had described an apical cell in the embryo of orchids.

One general result of the work on the embryo since Hanstein's time has been to discredit phylogenetic theories based on its early history. Indeed, it was hardly to be expected that a small mass of meristem, developing within a confined space and feeding parasitically on the tissues of the mother-plant, should preserve ancestral features, and one is surprised to find a morphologist with the experience and the wide grasp of Hanstein attaching so much importance to the succession of divisions within such a body. The conscientious student finds it a laborious task to follow the work done in plant embryology during the period which succeeded the publication of Hanstein's great paper. No wonder that when the end is seen to discredit rather than crown much of that work, when he realises how little has been gained as a result of so much patient toil, he is apt to renounce the whole subject in disgust. Yet in Science we dare not rule out the unexpected, perhaps even less in morphology than elsewhere. Hanstein and his successors did good service when they described the growth of the pro-embryo from the fertilised egg-cell, its division into

[1] Korschelt in 1884 revived the hypothesis that the growing points of some Angiosperms at any rate increased by means of an apical cell. He worked chiefly on aquatic plants. His views have not been accepted.

suspensor and embryo, the general development of both, and the appearance of external and internal differentiation in the embryo before germination.

Some of Hanstein's general conclusions as to internal anatomy have become the common property of text-books; for instance, the early differentiation of dermatogen in the embryo, and its subsequent development into the epidermal system. He was less successful in demonstrating the initial independence of plerome and periblem and their relation to the vascular cylinder of the mature stem.

The early differentiation of plerome and periblem from the internal tissues of the embryonic axis, and their continued formation at the growing points of stem and root respectively, are processes which demand the most careful investigation, on account of their bearing on the stelar hypothesis.

Dr. Schoute's work on the exact relationship of plerome and periblem at the growing-point to the central cylinder and cortex as differentiated in the older regions of the same axes, whether stem or root, is very important. He accepts Professor Van Tieghem's definition of the stele as the solid cylinder of root or stem enclosed within the endodermis. The endodermis itself, of course, is considered as belonging to the cortex, because in the root its cells are opposite the radial files of the inner cortex, and, indeed, form the inmost rank of those files. This is assumed to indicate a common origin by repeated tangential division. The cells of the pericycle—the outermost layer of the stele—alternate with those of the endodermis. As a rule there is no corresponding radial arrangement in the cortical tissue of the stem, but where such exists—as in the stem of *Hippuris*—the endodermis is again included in it and terminates it.

Using the microtome as an instrument of precision, Dr. Schoute in 1903 published the most careful observations on the growing-points of roots. His aim was to determine whether the limit between plerome and periblem (Hanstein) corresponded with that between stele and cortex (Van Tieghem). For this purpose Dr. Schoute was, of course, obliged to choose roots in which the plerome is clearly distinguished from the periblem at the growing-point. In the end he obtained precise results in three species: *Hyacinthus orientalis*, *Helianthus annuus*, and *Linum usitatissimum.* In each of these the periblem passed into the cortex, its inner layer becoming the endodermis, and the plerome gave rise to the stele only.

Owing to difficulties of observation, arising chiefly from the insertion of leaves close up to the growing-point and displacements in the original stem-structure consequent on this habit, Dr. Schoute was not equally successful in his work on stems. *Hippuris vulgaris* was the only species to give definite results. In this species he found that the plerome gave rise not only to the stele, but also to the endodermis, and to the two or three layers of cortex immediately beyond it. If these results are well founded the limit between plerome and periblem does not correspond with that between stele and cortex in the stem of *Hippuris*. Moreover, doubt is thrown on the assumption made by all previous observers that rows of cortical cells arranged in radial files must be of common origin.

Observations on a single species, however well attested, form a slender basis for conclusions regarding stems in general. Nor have Dr. Schoute's observations escaped criticism. Dr. Kniep has since examined the growing-point of *Hippuris*, and believes that he can identify plerome with central cylinder, and periblem with cortex, even in this test case. However this may be, no one denies the obscurity of stem anatomy in this respect compared to that of the root, nor the cause of that obscurity. The continuity of the stem stele is perpetually interrupted by the insertion of the leaf-traces, just as the symmetry of the stem growing-point is destroyed by the formation of leaf rudiments close up to its apex.

The stelar hypothesis is essentially an assertion of the real homology between the vascular systems of stem and root throughout all vascular plants. This was pointed out to me more than twenty years ago by Dr. D. H. Scott, and it has been the sheet anchor to which I have since clung through much stress of morphological weather. No difficulty arises so long as we are dealing with roots only, or with the stems of those Vascular Cryptogams in which the vascular system

is a closed cylinder, without gaps at the insertion of the leaf-traces. In such plants the vascular cylinder is as well defined as in all roots, and can be described in the same terms. But the case is quite different in the stems of Phanerogams, where to all appearance the primary vascular cylinder is a system built up of leaf-traces, embedded in a parenchymatous matrix. And the early anatomists were faced at once by this problem in its crudest form. Beginning with the anatomy of Phanerogams they first became acquainted with the primary structure of the Dicotyledonous stem. That of the root was not clearly understood until many years later; perhaps because anatomists attempted to interpret it by reference to the skeleton of the stem, and in the same terms. But there is nothing in the vascular anatomy of the root to correspond with the leaf-trace, and the leaf-trace is the vascular unit of stem-structure in all Phanerogams. Here, as elsewhere, confusion of nomenclature went hand in hand with confusion of thought, and it is difficult to say which was cause and which effect.

Even when the facts of root-structure were accurately known, the conception of the leaf-trace bundle as the structural unit continued to be a stumbling-block. In 1877 De Bary published his monumental work on Plant Anatomy, and, though it still keeps its place as the great book of reference on that subject, his descriptions of root anatomy appear to the modern botanist to be written in a dead language. When he calls the vascular axis of the root a 'radial bundle' it is quite clear that he regards this as a purely formal term, not implying any true homology between the leaf-trace bundle of the stem and the axial core of the root. He does not, indeed, consider a bundle as a unit: he defines it as a compound structure 'formed of tracheids and sieve-tubes definitely grouped.'[2] But the word 'bundle' was already impressed with another superscription. However defined originally, it had connoted the unit of stem-structure to a generation of botanists. With that connotation, De Bary's use of the term is in hopeless conflict. Moreover, the conception underlying that use was already out of date in 1877. Modern anatomy dates from 1871, when Professor Van Tieghem published the first of his great series of memoirs on the subject. In these the axial core of the root was treated as equivalent to the whole system of leaf-trace bundles in the stem, though the word 'stele' was not yet invented. This conception gained ground from the first; it was popularised by the happy choice of a name in 1886. From that date the stelar hypothesis has replaced all other schemes of vascular anatomy. The advance then made on all previous generalisations has been shown by the new impulse given to research, and the comparative simplicity introduced into text-book anatomy.

We cannot claim equal simplicity, I fear, for the technical language of research in this subject, and this alone should inspire caution, for obscurity of language rarely persists where there is no corresponding obscurity of thought.

No one now doubts that the central cylinder of the root in Phanerogams is far more closely comparable to the leaf-trace cylinder of the stem than to any one of the traces within it. Yet when the comparison becomes detailed difficulties are constantly arising. Where, for example, there is a medulla in the root it certainly forms part of the stele, which is a solid cylinder sharply defined by the specialised endodermis surrounding it. But the leaf-traces in the young stem surround a massive cylinder of parenchyma, precisely resembling the parenchyma of the cortex, with which it is in apparent connection through the gaps between the leaf-traces. Even the secondary formations do not completely divide one system from the other. When a specialised endodermis is present it is not so clearly defined as in the root: in many cases it is not present—in other words, there is no cell-layer outside the leaf-trace cylinder which is differentiated in any way from the surrounding tissues. In a few instances—most baffling of all—an endodermis surrounds each leaf-trace.

The stele in the stem of Phanerogams is not of necessity a morphological fiction because in many stems its precise limits cannot be determined. If, indeed, the word be used as a descriptive term its value is seriously impaired by every instance in which it fails to describe stem-structure with precision.

[2] *Comparative Anatomy of Phanerogams and Ferns.* 1st Eng. ed., 1884, p. 400.

But morphology is not merely descriptive. If we suppose that the stem-stele in remote ancestors of the Phanerogams was as well defined as that of the root and clearly comparable to it, we may attach a real morphological meaning to the term when applied to modern Phanerogams, provided we can show cause to believe that what we call the stele in their stems represents the ancestral stele. Its tissues will then have a history distinct from those of the cortex, though not clearly separated from them. The burden of proof, however, certainly lies with those who assert that an apparently continuous and uniform tissue can be separated into two parts of distinct origin.

The evidence advanced is of two kinds—one founded on the comparative anatomy of stems, and the other on the history of the tissues in the individual plant. Dr. Schoute has argued the case with great skill from the first point of view in his 'Stelärtheorie.' Depending to a large extent on his own researches, he has collected a great body of evidence to show that in the stems of Angiosperms a specialised layer is commonly distinguished from adjacent tissues either by the peculiar thickening characteristic of the endodermis in the root, or by the presence of starch in its cells. He shows that such a sheath surrounds the vascular cylinder in a very large proportion of the Dicotyledons examined, and in a majority of the Monocotyledons. Among Gymnosperms it occurs but rarely. Observing that the Angiosperms in which this bundle-sheath is obscure or wanting are commonly closely related to species in which it is perfectly well defined, Dr. Schoute concludes that its absence in such cases must be attributed to reduction.

Allowing that such a layer is as general among Angiosperms as Dr. Schoute believes, grave doubts may still exist as to its homology with the endodermis of the root. The latter is defined not only by its thickened walls, but also by the position of its cells. They form the inmost rank of the series of radial files which distinguish the inner cortex, and the morphological endodermis—the phlæoterma, as Strasburger calls it—can usually be distinguished by this purely morphological character, even when its walls are unthickened. In the stem, however, the cells of the inner cortex are not radially arranged, except in rare cases, such as *Hippuris*. Thus, there is no morphological criterion to distinguish the phlæoterma, or inmost cortical layer of the stem, from adjacent tissues. The bundle-sheaths distinguished by their thickened walls or by the presence of starch in their cells are physiologically similar; they play a definite part in the economy of the stem, but the presence of either character must depend mainly on the demands of the conducting or assimilating system, and need not imply the morphological identity of such layers with each other, or with the layer performing a similar function in the root.

Turning now to the second class of evidence—that drawn from the history of the tissues in the individual plant—we have already seen that the differentiation of plerome from periblem is far less definite at the growing-point of the stem than at the root. Doubts have even been thrown on the identity of plerome and periblem with stele and cortex respectively. But we have not yet followed the development of the tissues of the embryo into those of the seedling.

The normal seedling[3] of all Phanerogams consists at first of cotyledons, hypocotyl, and root, the plumular bud being still rudimentary. The primary root lies as a rule in a straight line with the primary stem, or hypocotyl. The hypocotyl is commonly the first part of the embryo to lengthen, and then its xylem is lignified a little earlier than that of the root or even that of the cotyledon. But when—as in many Monocotyledons—the base of the cotyledon lengthens first, lignification begins in that region and advances through the hypocotyl to the primary root.

The anatomy of the seedling at this epoch has lately been investigated by many independent observers. They constitute, indeed, the third school of embryology to which I have referred as completing the work of two earlier schools—namely, morphologists of the type of Irmisch and students of early embryology like Hanstein and his school. But though the subject is limited to a short period in the history of the plant, and to one in which its vascular structure

[3] By this qualification I mean to exclude cases in which the young seedling is very greatly reduced.

is comparatively simple, yet it has been attacked from different sides, and the attempt to give a concise account of the results attained is beset with difficulties. For the present, however, I propose to consider only their bearing on the stelar hypothesis.

Indeed, seedling anatomy becomes extremely important when the vascular system of the root is compared with that of the stem. For in the seedling we have a complete and simple vascular skeleton, which at one end belongs to the primary root of the plant, and at the other to its primary stem. There must be an intermediate region in which stem-structure passes into root-structure, and the method of transition should at least suggest, if it does not precisely determine, the relation in which they stand to each other. For this reason great value has been attached by anatomists to the transitional region of the main axis. It was not completely investigated, however, until the microtome was introduced into botanical practice, for the change of structure is often very abrupt, and cannot be studied in detail unless all possible sections are present in their proper order.

In this, as in other branches of modern anatomy, Professor Van Tieghem was first in the field. In his memoir of 1872, 'Sur les Canaux Secréteurs des Plantes,' he described the course of the bundles in the hypocotyl of *Tagetes patula*, an example of the second type of transition given in his text-book (1886). The three types were, indeed, already identified in 1872, for the first and third are defined in a footnote appended to the description of *Tagetes*.

Tagetes patula was, of course, examined in 1872 with the aid of hand-sections only. Two traces enter the hypocotyl from either cotyledon, and form in the end a diarch root. The plane passing through its xylem poles is the median plane of the cotyledons. In the upper part of the hypocotyl this plane bisects the space which separates the two bundles entering each cotyledon. So far the description of *Tagetes* given in 1872 is identical with the generalised account of type 2 in the text-book (1886). But a detail of some importance is mentioned in the description of *Tagetes* which does not reappear in the definition of type 2. In each of the spaces just mentioned—called, for convenience, xylem spaces, because they lie above the xylem poles of the root—lies an isolated xylem element, the direct continuation of the most external element in one of the root poles, and this element comes to an abrupt end higher up.

Thus Professor Van Tieghem has tacitly assumed that *Tagetes* is exceptional in this respect, and this view was also adopted by Professor Gérard in his laborious and accurate paper of 1881. He describes the transitional phenomena of a number of Dicotyledons, among them *Tagetes erecta*. Not only is the transition in this species exactly the same as that in *T. patula*, but the author records a similar isolation of primitive xylem elements in *Raphanus niger*, *Ipomœa versicolor*, and *Datura Stramonium*, still treating the arrangement as exceptional.

These details are important, because if certain protoxylem elements belonging to the root are not continued upwards in regular succession into the cotyledonary or plumular bundles, but end abruptly in hypocotyl or base of cotyledon, there is not that complete correspondence between stem- and root-structure which is assumed in Van Tieghem's three types. In all of them the xylem and phlöem bundles of the root are continued into the cotyledons or plumule. On their way through the hypocotyl they may divide or be displaced, and the xylem bundles 'rotate'—that is, they turn on their own axes until the protoxylem is internal. But all the elements present in the root are continued upwards in regular succession, and are simply rearranged in the upper part of the seedling. This is one of the main arguments advanced by Professor Van Tieghem to support his view that the steles of root and stem are identical.

According to most later observers, however, such temporary prolongation of the root-poles upwards as that described by Professors Van Tieghem and Gérard in a few instances, and considered by them as exceptional, is really of general occurrence. The protoxylem elements, indeed, are not commonly isolated from the main xylem of the cotyledonary traces as in *Tagetes*, but are in more or less complete contact with them on either side. Such contact is approached in *Raphanus niger*, where it is very clearly suggested in Professor Gérard's figures.

There is then a real difference of opinion on a question of fact between Professor Van Tieghem and his school, on the one hand, and certain modern embryologists on the other. Three distinct views are now held as to the interpretation of the isolated xylem elements in the hypocotyl of *Tagetes*. I shall try to state them as fairly and concisely as possible.

Professors Van Tieghem and Gerard treat *Tagetes* and the genera which resemble it as exceptional, because part of the external xylem of the root is continued upwards between the cotyledonary traces, and dies out in the base of the cotyledon. They consider that the remainder of the external xylem turns on itself and becomes internal in the usual way.

Professor Gravis and his pupils think that a similar prolongation of the xylem poles of the root into the hypocotyl or cotyledon is the rule, and that they terminate there abruptly. But in most cases this vestigial root-xylem is not isolated; it is in contact on either side with the early xylem of the cotyledonary traces, and is therefore apt to be confused with it. The characteristic shape of so many cotyledonary traces arises in this way. They are often called double bundles, but according to Professor Gravis they are more than double, for each really consists of two traces in close contact with the last vestige of root-xylem. The latter always disappears higher up in the cotyledon, and the two traces may then unite into a midrib, with or without lateral branches. As a consequence of this view, Professor Gravis considers that there is no morphological continuity in the hypocotyl between the vascular systems of root, stem, and leaf.[4] Their traces are merely in contact sufficiently intimate for physiological purposes. There can, therefore, be no true homology between the central cylinder of the stem and that of the root.

The third view is that of M. Chauveaud, who has been engaged for upwards of twenty years in following the development of the vascular elements in the hypocotylar region and its neighbourhood. He agrees with Professor Gravis that the presence of external xylem is the rule in the hypocotyl and in the base of the cotyledon. But he considers that this external xylem belongs to the primitive structure of hypocotyl and cotyledon as well as to that of the root. We have already said that the vascular system of seedlings is first differentiated in the hypocotyl, base of cotyledon, and base of primary root. In all these regions M. Chauveaud thinks the primitive stele to be root-like—in his own phrase it belongs to the 'disposition alterne.' The xylem alternates with the phloem, and its development is centripetal. This primitive formation, however, is permanent only in the root, and commonly in the lower part of the hypocotyl also. In the upper part of the hypocotyl and in the base of the cotyledons the first xylem elements are fugitive. They disappear so early that as a rule they are missed completely by the anatomist, who is apt to prefer well-differentiated tissues, and therefore to choose seedlings which are past their first youth.

In considering the theory of stelar evolution in which M. Chauveaud has correlated his own long series of observations with the results of other embryologists, I shall confine myself strictly to the question now under discussion—namely, the extent to which the stele of the young stem in Phanerogams can be considered to represent that of the root. Professor Van Tieghem, as we have seen, considers them completely homologous, while Professor Gravis denies that they are homologous at all.

M. Chauveaud occupies a middle position. If I understand his views rightly, he considers that there is an early phase in the development of the seedling in which the stele of the hypocotyl—at that time the only representative of the stem—is developing on exactly the same lines as the stele of the primary root, and is, in fact, continuous with it. At that epoch each cotyledonary trace is also developing on the same plan. It belongs to the same phase of evolution, and in many species of Dicotyledons the insertion of the cotyledons is the

[4] A. Gravis, *Recherches . . . sur le 'Tradescantia virginica,' Mém. de l'Acad. royal* . . . Tome lvii., Bruxelles, 1898. See account of hypocotyl (pp. 28-32), including insertion of cotyledon (pp. 31-32). Also memoir by same author on *Urtica dioica* (1885), footnote on p. 117. Cf. also Mr. R. H. Compton's paper in *New Phytologist*, xi., p. 13, 1912.

gaps. This process is said to be exhibited in the young epicotyl.[7] Until this point is cleared up the exact relationship of the vascular cylinder of the stem to that of the root will remain obscure. As a matter of convenience the stem-cylinder will, no doubt, be called a stele, even though anatomists should acknowledge that it cannot be considered as strictly homologous with the stele of the root. Much confusion of thought would, however, be avoided if the two structures were not treated as strictly comparable.

There can be very little doubt that the insertion of leaves has brought about the change, and I might suggest here that the insertion of leaves on an exarch stem-stele would be an interesting subject for research. The literature of the subject is scattered, and its treatment seems to me very incomplete. An exarch axis bearing leaves is, of course, exceptional, but more common among extinct plants than among recent species. So far as my very cursory examination of the literature has gone, it seems a general rule that the leaf-traces are inserted on the xylem poles of the stele.[8]

Hitherto I have considered modern embryology in relation to a single problem of internal anatomy—namely, the comparison of the vascular system of the stem to that of the root. But the evidence of embryology is also of great weight in questions of internal morphology and phylogeny.

Several questions of this kind are discussed by Hanstein, from whose classical paper I continue to date. For example, his account of the embryo of Monocotyledons suggests two distinct problems. One belongs to formal morphology—namely, the question whether a terminal member can be considered as a leaf. The other is a question of phylogeny: whether Dicotyledons are derived from a monocotylous ancestor or Monocotyledons from a dicotylous form. Both these questions I have discussed elsewhere,[9] and only refer to them now as examples of the way in which seedling anatomy has proved complementary to that of the older embryologists.

The most obvious interpretation of Hanstein's observations is that the single cotyledon of Monocotyledons is equivalent to the pair found in Dicotyledons. This would imply that Dicotyledons were derived from an ancestor with one cotyledon, apparently terminal, which gave rise to the existing pair by a process of fission. But other interpretations were always possible, and the terminal hypothesis received a shock when Count Sohms-Laubach discovered that in certain Monocotyledons the single cotyledon is lateral from the first.

The comparative antiquity of Monocotyledons and Dicotyledons has been one of the first questions raised by the study of seedling anatomy. It is remarkable that both the hypotheses founded on work of this kind assert the greater antiquity of the dicotylous form. But if the cotyledonary member of Monocotyledons is derived from one or both cotyledons of an ancestral pair, it cannot be considered as terminal. Thus the evidence of seedling anatomy bids fair to settle both these problems, as I think it will settle others of the same kind mentioned by Hanstein.

The descriptive work of Irmisch and the school he represents has been carried on of late years by an American naturalist, Mr. Theo. Holm, with all the technical advantages given by modern instruments of research. His papers are commonly written with systematic intention, but the external characters of the species he describes are correlated with their internal anatomy, and the structure of the adult form is traced from its origin in the seedling. His monograph on *Podophyllum peltatum* is an example of this method, and illustrates its advantages in a very striking way. But it is becoming much more usual to compare the seedling with the adult form, as may be seen in two monumental works now being published in parts: 'Das Pflanzenreich,' edited by Engler, and 'Lebens-

[7] Jeffrey, *The Morphology of the Central Cylinder in the Angiosperms*. Trans. Canadian Inst., vi., 1900.

[8] D. H. Scott, *Studies in Fossil Botany*, 1908, p. 97 (*Sphenophyllum*); C. E. Bertrand, *Remarques sur le 'Lepidodendron Harcourtii,'* 1891, p. 109; M. Hovelacque, *Recherches sur le 'Lepidodendron selaginoides,'* 1892, p. 150; F. O. Bower, *Origin of a Land Flora*, p. 334 (*Selaginella*), 1908; C. E. Jones, *Trans. Linn. Soc.*, ser. 2, vii., 1905, p. 19 (*Lycopodium*).

[9] E. Sargant, *Ann. of Bot.* xvii., p. 1, 1903, and *id.* xxii., pp. 150-2, 1908.

geschichte der Blütenpflanzen Mitteleuropas,' edited by Kirchner, Loew, and Schröter.

In a very useful paper on modern developments of seedling anatomy Mr. Compton has pointed out that the subject has been attacked from several divergent points of view. I have already referred to the work of M. Chauveaud and Professor Gravis, and have now come to that of a number of English botanists, whose aim—as Mr. Compton observes—is mainly phylogenetic. They are even more clearly distinguished by their methods, which are those of comparative anatomy. Instead of following the development of the seedling of a single species from germination to the age at which its cotyledons begin to decay, as M. Chauveaud has done in a number of carefully selected instances, they have compared the seedlings of different species and different genera at about the same age, generally choosing the epoch at which the tissues of cotyledon, hypocotyl, and primary root are most completely differentiated. There is nothing new in this treatment of the subject. It was employed in 1872 by Professor Van Tieghem [10] in his paper on the anatomy of Grass seedlings, in which he compares them with other Monocotyledons of the same age. Much greater precision is possible, however, now that the microtome has come into general use.

The literature of this subject has increased rapidly of late years. The list of references in the footnote [11] appended to this paragraph is, I fear, far from complete. But it is no part of my plan to review this work critically. The time is, perhaps, not ripe for such a review, and certainly the time at my disposal to-day is quite insufficient for it. Perhaps I may be allowed to offer some general remarks, first on the method itself, and then on the criticisms it has encountered.

[10] Prof. Van Tieghem, *Ann. Sec. Nat.*, ser. 5, xv., p. 236, 1872.

[11] The following references are arranged alphabetically:—

Arber, A., The *Cactaceæ* and the Study of Seedlings. *New Phyt.*, IX., p. 333, 1910.

Compton, R. H., An Investigation of the Seedling Structure in *Leguminosæ*. *Linn. Soc. Journ. Bot.*, xli., p. 1, 1912.

de Fraine, Ethel. The Seedling Structure of certain *Cactaceæ*. *Ann. Bot.*, XXIV., p. 125, 1910.

Hill, A. W. The Morphology and Seedling Structure of *Peperomia*. *Ann. Bot.*, XXI., p. 395, 1906.

Hill, T. G. On the Seedling Structure of certain *Piperales*. *Ann. Bot.*, XX., p. 160, 1906.

Hill, T. G., and de Fraine, Ethel. On the Seedling Structure of certain *Centrospermæ*. *Ann. Bot.*, XXVI., p. 175, 1912.

Hill, T. G., and de Fraine, Ethel. On the Influence of the Structure of the Adult Plant upon the Seedling. *New Phyt.*, XI., p. 319, 1912.

Hill, T. G., and de Fraine, Ethel. A Consideration of the Facts relating to the Structure of Seedlings. *Ann. Bot.*, XXVII., p. 258, 1913.

Lee, E. Observations on the Seedling Anatomy of certain *Sympetalæ*. *Ann. Bot.*, XXVI., p. 727, 1912.

Sargant, E. A New Type of Transition from Stem to Root in the Vascular System of Seedlings. *Ann. Bot.*, XIV., p. 633, 1900.

Sargant, E. The Origin of the Seed Leaf in Monocotyledons. *New Phyt.*, I., p. 107, 1902.

Sargant, E. A Theory of the Origin of Monocotyledons, founded on the Structure of their Seedlings. *Ann. Bot.*, XVII., p. 1, 1903.

Sargant, E. The Evolution of Monocotyledons. *Bot. Gaz.*, XXXVII., p. 325, 1904.

Smith, Winifred. The Anatomy of some Sapotaceous Seedlings. *Trans. Linn. Soc.*, series 2. Bot. VII., p. 189, 1909.

Tansley, A. G., and Thomas, E. N. Root Structure in the Central Cylinder of the Hypocotyl. *New Phyt.*, III., p. 104, 1904.

Tansley, A. G., and Thomas, E. N. The Phylogenetic Value of the Vascular Structure of Spermophytic Hypocotyls, *Brit. Assoc. Report*, 1906.

Thomas, E. N. A Theory of the Double Leaf Trace, founded on Seedling Structure. *New Phyt.*, VI., p. 77, 1907.

The references given above refer to Angiosperms only, but so much work of a

To compare the structure of organisms with each other is, of course, the recognised method of comparative anatomy, of systematic botany, and, in fact, of all branches of morphology. The great difficulty in all such work is to distinguish between adaptive characters of comparatively recent origin and the characters inherited from remote ancestors. The history of systematic botany is very instructive in this respect. Systematists discovered by degrees, and by means of repeated failures, that characters could not be picked out as important for purposes of classification on *à priori* grounds. No character is of uniform importance throughout vascular plants, for example. On the contrary, it may be of great value in the classification of one group and worthless in another, though closely allied. Generations of botanists have laboured to build up the Natural System in its present form, and it is constructed from the ruins of abandoned systems. We all agree now that the guiding principle in all morphology is that our classification should represent relationships founded on descent only. But the Natural System was complete in its main features before that principle was understood. It represented the feeling for real affinity developed in botanists by the study of plant form, independently of any theory as to the cause of such affinity.

This, of course, is the commonplace of botanical history, but we do not always realise that all morphological work is done under similar conditions. The only valid appeal from criticism is to the future: a new method is approved by its results. Therefore, to embark on a new branch of morphology is a real adventure. The morphologist risks much time and much labour. He knows that the evidence which he proposes to gather painfully, to test critically, to present logically, may, after all, prove of little consequence, and he has to depend on his own instinct to lead him in the right course. In his degree he resembles Columbus, to whom a few sea-borne seeds and nuts meant a new continent.

Hence the difficulty of criticising recent work. When once a conclusion of some importance has been formulated it may be tested by evidence drawn from other branches of research. Until that time criticism from outside is of little value. Those who are working at the subject must, of course, form their own opinion on its possibilities, for each has to decide for himself whether he shall continue on those lines.

The subject of seedling anatomy is no longer very new. It is too late now to debate on the *à priori* probability of ancestral characters surviving in the young seedling. No one doubts that a vascular stump sometimes persists after the organ it originally supplied has disappeared.[12] Therefore there is no glaring improbability in the suggestion that the vascular skeleton of the young seedling may afford a clue to the structure of a remote ancestor. But this is only saying in other words that botanists are justified in giving the subject a fair trial. That trial is now proceeding. Some general conclusions have been formulated already, but they have not yet stood the test of time. In all probability the final judgment on this subject will be given by a future generation of botanists on evidence not as yet before us. In the meantime we shall all form our own opinion as to

similar nature has been done lately on Gymnospermous seedlings that I add a list of the principal papers:—

Dorety, Helen A. Vascular Anatomy of the Seedling of *Microcycas calocoma*. *Bot. Gaz.*, XLVII., p. 139, 1909.

Hill, T. G., and de Fraine, Ethel. The Seedling Structure of Gymnosperms. I., *Ann. Bot.*, XXII., p. 689, 1908. II., *id.* XXIII., p. 189, 1909. III., *id.* XXIII., p. 433, 1909. IV., *id.* XXIV., p. 319, 1910.

Matte, H. L'appareil libéroligneux des Cycadies. Caen, 1904.

Shaw, F. J. F. The Seedling Structure of *Araucaria Bidwillii*. *Ann. Bot.*, XXIII., p. 321, 1909.

Sykes, M. A. The Anatomy of *Welwitschia mirabilis*. . . . *Trans. Linn. Soc.*, 2. Bot. VII., p. 327, 1910.

Thiessen, Reinhardt. The Vascular Anatomy of the Seedling of *Dioon edule*. *Bot. Gaz.*, XLVI., p. 357, 1908.

[12] *Cf.* the discussion of the homology of the Orchis-flower in Ch. Darwin's *Fertilisation of Orchids*, chap. xiii., p. 235 in second ed., 1888.

the prospects of the method. Speaking for myself, I think that it has already thrown much light on embryological problems, and is likely to throw more.

At the end of this very short and imperfect sketch of the progress of botanical embryology in recent years, it is natural to look back and attempt to estimate the importance of the whole subject and its relation to other branches of botanical science. I have treated it from the morphological side only, but clearly every department of botany must deal with the immature plant as well as with the adult form. For example, the struggle for existence between two species in any particular locality must be profoundly affected by the characters of their seedlings. If one species should gain a decided advantage over the other early in life, the vanquished species may never live to form seed, and may thus disappear from that neighbourhood in the first generation. This is an extreme case to show the importance of considering seedling structure in problems of ecology and distribution.

The internal structure of seedlings is certainly a department of vegetable anatomy, just as their adaptation to the conditions of life is a department of vegetable physiology. That the connection between embryology and systematic botany must be equally close seems at first sight to be beyond dispute, but the exact nature of that connection is as yet undetermined. In systematic botany we have the net result of an enormous mass of experience. Generations of botanists have examined and described the external characters of plants; they have arranged and rearranged them in groups until at last the instinct for affinity has been satisfied. In this continual sifting of characters some have been separated out as generally of systematic importance—the floral characters, for example, and those of the seed. Certain features of the embryo are included among those characters, as already mentioned, but, on the whole, systematists have dealt exclusively with the adult plant. The embryo itself has been treated rather as a portion of the seed than as an individual.

It would be rash to assume that seedling characters have been disregarded by systematists because they were too busy with the fully-developed plant to pay proper attention to the young forms. In all probability some of the earlier botanists examined the external characters of seedlings and rejected them when they proved of little systematic value. But embryology, like the other branches of botany, entered on a new phase when the compound microscope came into general use. It was commonly denied that the anatomical characters of mature plants had systematic value until the test case of fossil botany was decided in favour of anatomy. We need not be surprised that conclusions drawn from the new embryology—that is, the embryology which includes internal characters as well as external—sometimes appear to conflict with the results of systematic botany, and it does not necessarily follow that embryological evidence is of no systematic value. The fault may lie with the embryologists, who, being human, do occasionally misinterpret their facts, or possibly the natural system may need some modification in the light of new knowledge. When both explanations have failed to account for the discrepancy in a number of cases we may be forced to give up looking for phylogenetic results from embryology.

And so in the end the appeal is again to Time, who—as Milton says—devours

'No more than what is false and vain,
And merely mortal dross.
So little is our loss,
So little is thy gain.'

The following Papers were then read :—

1. *On the Nature of Life.* *By* Professor J. Reinke, *Ph.D.*

The more, after the united endeavours of zoologists and botanists, the essential concordance of animal and vegetable life has come to light, the more the fundamental problem of science has come to the fore: What is the nature of life and how is it to be explained?

Often people have tried to solve this problem more in accordance with pre-

conceived opinions than with the methods of exact science, that simply asks and inquires, unconcerned for the answer.

In the period preceding ours the dogma prevailed that the phenomena of life ought to be interpreted merely mechanically. A plant and an animal ought to be mechanisms, machines, nothing else, but of so complicated a construction that analysis is even yet unable to explain this merely mechanical machinery. In still older times people believed a *vis vitalis* to be active in the organism that did not accord with any other power in nature and that caused life. But this *vis vitalis* came more and more into contradiction with the principles of science until at last the contrary doctrine arose, that life was only a complicated example of the processes predominant in lifeless nature. This opinion was founded on the knowledge that plants and animals are composed of chemical combinations known also outside the organisms; that these combinations influence one another according to the universal chemical laws; that everywhere in the living body physical powers are active. In this manner physiology becomes the chemistry and physics of organisms.

But the greater the progress in experimental physiology, the better we learn to use our knowledge of non-living matter for the explanation of the processes of life, the more we understand that a complete physico-chemical analysis is impossible for any important process of life. Behind all the physico-chemical facts found out by our physiological studies an unknown factor is hiding, an x not to be solved by levers and screws and chemical reagents. For my part I refuse both the exclusive vital and the exclusive mechanical dogma, but I do not wish to subordinate the living to the lifeless matter and to draw from the dominion of lifeless nature only parallels for the explanation of life.

I am sure that the laws of energy are valid in the organism as well as in unorganised nature, and that the change of matter and of power in animals and plants depends only on them. Life is based upon such transformations of energy—I call them 'Elementarprozesse'—and these elementary processes are bound to elementary mechanisms in the cells of animals and plants. These elementary processes and elementary mechanisms are not thrown together without order in the living body: they are united by an invisible string or chain and this invisible chain or force that maintains the order among the elementary processes represents the true difference between life and any event in lifeless nature. I call it the 'Lebensprinzip.' The single elementary processes are accessible to physiological analysis; not so the 'Lebensprinzip.' Therefore the elementary processes form only one part of the living creature: the 'Lebensprinzip' forms the other part. By the latter the former are united to a living unity, an individual; and it can continue the individual in its offspring. In the ontogeny each stage of development from the egg-cell to the adult state is united by the 'Lebensprinzip.'

Each elementary process in animals and plants can be imagined by itself; not so the 'Lebensprinzip.' It shows only the relations among the elementary processes or mechanisms, therefore it is a law, that like all laws is invisible and impalpable. The 'Lebensprinzip' is the ordered connection of the elementary mechanisms within the living body; its ordered efficacy excludes an accidental aggregation of the elementary mechanisms in the body of plants and animals. Therefore life has its own laws as well as light, heat, chemistry: which does not exclude the fact that the physico-chemical laws reign in the elementary processes of a living body. Thus any mystical interpretation of the 'Lebensprinzip' is excluded, as it was applicable to the old *vis vitalis*. The 'Lebensprinzip' is no force or power: it is a principle of succession, of order, of regulation, of harmony.

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2. *Ammonium Humate as a Source of Nitrogen for Plants.* *By* Professor W. B. Bottomley, *M.A.*

In a communication to this Section last year attention was called to the effect of soluble humates on plant growth. Further investigations show that ammonium humate can supply the nitrogen need of plants if soluble phosphates and potassium salts are present in the culture solution.

Pure ammonium humate was obtained by extracting bacteria-treated peat with distilled water, precipitating humic acid from this extract by hydro-

chloric acid, and after repeated washing of the humic acid adding just sufficient ammonium hydrate to dissolve it. This was then diluted with distilled water in the proportion of 1 humate to 200 water.

Maize seedlings, obtained by germinating maize seeds in moist sand and when the roots were a few inches long cutting off the seed, were used for four series of culture experiments, two plants in each series. After six weeks' growth the following results were observed :—

Series 1.—Distilled water. Plants died.

Series 2.—Ammonium humate alone. Plants grew well in this at first; later showed signs of starvation. Root development very strong, equal to roots in normal culture solution 15 to 25 cms. long.

Series 3.—Ammonium humate with phosphates and potassium. Plants showed stronger growth than those in normal culture solution, being taller and having stouter stems and larger leaves. The root development was remarkable. The majority of the roots were 30 cms. long and five roots measured to 45 cms. each.

Series 4.—Normal culture solution (Detmer). Plants made healthy normal growth. Roots 15 to 20 cms. long.

This effect of ammonium humate on the development of the root system and the general growth of plants has been further demonstrated by a series of experiments on pelargoniums, salvias, carnations, begonias, and balsams at the Royal Gardens, Kew; and on wheat, barley, oats, radish, turnips and tomatoes at Chelsea Physic Gardens.

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3. *Juvenile Flowering in* Eucalyptus globulus. *By* Professor F. E. Weiss, *D.Sc.*

Cases of juvenile flowering are known for quite a large number of plants, some of the most striking instances recorded being in the genus *Rosa*, in which seedlings still in possession of their seed-leaves bear a terminal flower on a stem not more than a few centimètres in height. Cockayne has recently drawn attention to numerous cases of juvenile flowering met with among New Zealand plants; and Diels, in his interesting book on 'Jugendformen und Bluthenreife,' gives instances of a number of plants, largely belonging to the Australian Flora, in which he has observed similar occurrences. In several cases Eucalypti, which usually show a marked difference between the foliage of the immature plant and the mature foliage, have been found in nature flowering on small shrublike plants still possessing leaves of the immature type. Thus the plant from Southern Tasmania, described by J. D. Hooker, under the name of *Eucalyptus Risdoni*, was regarded by von Müller, in his 'Eucalyptographia,' as only a form of *Eucalyptus amygdalina*, differing from the latter only in the possession of broad sessile leaves of immature type. It has been suggested that the cooler climate of Tasmania prevents this species of Eucalyptus from growing to proper vegetative maturity.

In a similar way *Eucalyptus pulverulenta* and *Eucalyptus melanophloia* seem to be juvenile flowering forms of *Eucalyptus Stuartiana* and *Eucalyptus crebra* respectively.

I have so far not seen recorded the occurrence of the same phenomenon in *Eucalyptus globulus*, but during the past year a case has occurred in my greenhouse. A young plant of this species, growing in a six-inch pot, was cut down after its first year's growth to the height of about two feet. One of the lateral buds then grew out and became the leader, developing in the autumn a number of flower buds in the axils of five pairs of leaves of the type usual to young plants—namely, broad and rounded at the base, bilaterally symmetrical and covered with bloom. During the winter the buds grew normally to full size, and the flowers of normal size opened during the month of June, when the plant was little more than two years old. Several of them were fertilised and have set seed. It is of interest to note that in the same greenhouse a plant which has been grown freely for many years has produced neither flower buds nor mature foliage. On the other hand, a plant two years of age, of which the main stem was cut back this spring to the dormant axillary buds of the cotyledons, threw up two shoots from these buds, one of which became a leader, and

this has developed a few flower buds which will, I hope, open next spring or summer. It is clear, therefore, that, as in the case of other species of this genus, *Eucalyptus globulus* is also able, under certain conditions, to produce flowers on juvenile plants.

4. *Histology of the Leptoids in* Polytrichum. *By* Margaret Hume.

The leptoids in *Polytrichum* do not deserve the name of sieve-tubes in any ordinary sense of the word. Their contents differ from those of the other living cells in never including starch grains or large drops of oil, but each leptoid has a nucleus. They are rich in connecting threads, which are especially thickly aggregated in the terminal walls, and are also abundantly present in the lateral walls, towards the ends of the cells. The threads occasionally show an arrangement into definite areas as in the sieve-plate, but are more frequently quite diffusely scattered. Where such plate-like areas occur there is no change in the thickness of the cell-wall. The area of the terminal wall is enormously increased by its bag-like shape, so that the end of one cell depends into the lumen of the next.

The connecting threads do not differ in structure from those found in the cortical cells, and they do not appear to undergo any progressive change into slime-strings, with accompanying alteration of the surrounding cellulose into callus.

Histological arguments in favour of the conduction of organised food materials by the leptoids must be based upon the elongated shape of the cells, the great area of their terminal walls, and the wealth of connecting threads, especially aggregated towards the ends of the cells.

From direct experiment, the conducting function of the leptoids seems, more probably, to be confined to albuminous materials, and not to be concerned with carbohydrates. The latter are possibly conveyed in the hydroids which, it seems likely, have not a purely water-conducting function.

FRIDAY, SEPTEMBER 12.

The following Papers were read :—

1. *Fossil Plants showing Structure from the Base of the Lower Carboniferous of Kentucky. By* Professor E. C. Jeffrey *and* Dr. D. H. Scott, *For.Sec. R.S.*

The specimens were collected by Prof. C. R. Eastman, near Junction City, Boyle County, Kentucky; they come from the nodule-bearing layer at the bottom of the Waverley shale, at the base of the Lower Carboniferous, and are among the oldest known land-plants with their structure preserved.

The following specimens have been investigated :—

1. *Calamopitys americana*, sp. nov.

A stem allied to *C. annularis* (Unger) : remarkable for the mixed pith, containing tracheides, and for the paired leaf-trace bundles in the wood. The leaf-base has the structure of *Kalymma*.

2. *Kalymma* petioles, no doubt belonging to *Calamopitys americana* or allied species.

3. *Calamopteris Hippocrepis*, sp. nov., a petiole of the *Kalymma* group, but with the bundles arranged in a horse-shoe form, and largely fused.

The above-mentioned fossils are clearly members of the transitional group, Cycadofilices or Pteridospermeæ.

4. *Archæopitys Eastmanii*, gen. et sp. nov.

A stem with dense secondary wood and numerous small mesarch strands of xylem scattered in the pith. Probably one of the Cordaitales, allied to *Pitys*.

5. *Periastron perforatum*, sp. nov.

A curious petiole with a median row of separate vascular bundles and large

lacunæ in the ground tissue. Clearly allied to the *P. reticulatum* of Unger. Whether a Pteridosperm or a Fern cannot be determined.

6. *Stereopteris annularis*, gen. et sp. nov.

A petiole, with a single large vascular bundle, somewhat resembling that of *Clepsydropsis* or *Asterochlæna* in form, but with solid wood, and external protoxylem. Cortex differentiated into several distinct zones.

Probably a Fern, with some affinity to the Zygopterideæ.

7. *Lepidostrobus Fischeri*, sp. nov.

One of the oldest known fructifications with structure. The axis is of an ordinary *Lepidostrobus* type, the sporangia have the usual columnar wall, and the spores are in tetrads.

A full account of these fossils will shortly be submitted to the Royal Society.

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2. *On a New Type of Ginkgoalian Leaf.* *By* H. HAMSHAW THOMAS, *M.A.*

In the Jurassic plant-bed of Cayton Bay, near Scarborough, a number of beautifully preserved leaves occur which belong to a new type. They are linear or oblanceolate in shape, with rounded or slightly bifurcated apices, short petioles, and dichotomising venation. The leaves are usually found in a mummified state; they can be readily detached from the rock, and yield beautiful cuticular preparations. The form of the stomata and subsidiary cells is very similar to that of other Ginkgoalian leaves, while they possessed the secretory tracts between the veins as seen in the modern form. The epidermal cells possess very characteristic papillæ.

These leaves form the type of a new genus *Eretmophyllum* with two species, a second form having been found at Whitby. The specimens provide a further illustration of the importance of the Ginkgoales in the Mesozoic vegetation, while they are an example of the interesting preservation of some Yorkshire plants and of the importance of the study of cuticular structure.

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3. *A New Species of Medullosa from the Lower Coal Measures.* *By* E. DE FRAINE, *D.Sc.*

The specimen consisted of a short length of stem surrounded by adherent leaf-bases, and occurred in a coal-ball obtained from the Lower Coal Measures of Lancashire.

The stem was of small size, the diameters of the transverse section being only 5 cms. × 1·5 cm., including the leaf-bases.

The vascular system of the stem consisted in the upper sections of three irregularly shaped outer steles, roughly triangular in outline; one of these steles branched during the length of stem available so that the lower sections of the series show a ring of four steles. The outer ring of steles encircles a small central strand or 'star ring,' which undergoes no change during the series, and forms the characteristic feature of the fossil. A narrow zone of periderm enclosed the vascular tissues of the stem.

The numerous leaf-traces passed out from the peripheral parts of the outer steles. The leaf-bases showed a typical *Myeloxylon* structure with numerous exarch collateral bundles and abundant gum canals, and the hypoderma was of the *Myeloxylon Landriotii* type. In the general structure of the steles and of the leaf-bases and in its histological details the stem shows a very close resemblance to *Medullosa anglica*.

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4. *The Pinna-Trace in the Filicales.* *By* R. C. DAVIE, *M.A., B.Sc.*

There are two main types of vascular supply to the pinnæ in the Filicales.

The 'marginal' type occurs generally from leaf-traces which have no hooks at their ends; the 'extramarginal' appears regularly in connection with leaf-traces possessing incurved hooks. The 'marginal' type is found, however, in

Aneimia and in some species of Dicksonia, in which the leaf-traces have more or less hooked ends.

Variations of the usual methods of pinna-supply appear in *Loxsoma Cunninghami* R. Br., *Onoclea sensibilis*, L., *Hymenophyllum demissum* (Forst.), Sw., and *Nothochlæna affinis* (Mett.) Moore, suggesting intermediate stages between the marginal and extramarginal types. In some species of Pteris and Hypolepis and in some of the Cyatheaceæ there is a combination of marginal and extramarginal types.

The supply to the ultimate pinnæ is always marginal, and the supply to the pinnæ in the earliest leaves is also marginal.

5. *The Centripetal and Centrifugal Xylem in the Petiole of Cycads. By* M. J. LeGoc, *B.A., Ph.D.*

The cycads possess a number of characters which may be considered as sign-posts pointing out the path followed by some of the higher plants in the course of their evolution from more primitive forms. A noteworthy example is the peculiar structure of the foliar bundle with its double xylem arrangement, one portion centripetal (cpx.), the other centrifugal (cfx.).

Two main interpretations of this structure have been given by different investigators.

(1) The foliar bundle is mesarch, agreeing closely with the *Lyginopteris* type.

(2) The bundle is mesarch only in appearance. In reality it is normal, and is the result of the xylem curving backwards into an inverted omega-like structure.

Observations.—My observations bear mainly on the transition from the cfx. into the cpx. at the base of the petiole.

In an adult petiole, though the bundles at the very base assume different forms, they possess, however, a common and constant character, *i.e.* the xylem is strictly and exclusively centrifugal; it is like the continuation of the stelar bundle. But this character is gradually lost as one passes higher up in the petiole; some of the rows of xylem are lateral, while here and there appear lignified cells decidedly centripetal. With the constant increase of the cpx. there is a corresponding decrease of the cfx., which becomes very much reduced and consists only of a few cells scattered in a matrix of parenchyma. In a young petiole the amount of lignified cfx. is small at the base, while disappearing altogether a short distance higher up, where the lignification of the cpx. has begun. Wounds produced in a young petiole have induced interesting structures. Large bundles made of transfusion cells have been formed in order to bring the severed bundles of the upper part into communication with the lower part of the petiole. In addition a considerable number of the neighbouring bundles have been influenced by the wound; the activity of the cambium has been increased, the cfx. and cpx. are joined laterally, and secondary xylem has been produced all round the bundles, which consequently have a concentric appearance.

Interpretation.—The arrangement of the xylem, cambium, and phloem elements in regular rows, separated by medullary rays at the base of petiole, has led some writers to suppose that the cfx. is of secondary origin. But this alone is no sufficient proof, because such structures are met with in primary tissues. If, however, we have constantly found the number of lignified cells in an adult bundle to exceed the number of cells included between the cambium and the first cpx. cell in a young petiole, we are necessarily led to the conclusion that secondary growth occurs at its base.

On the other hand, the cpx. is primary wherever it occurs; there is no trace of cambium in the vicinity, and the cells are well defined before undergoing the process of lignification.

But it is evident that a primary growth cannot be the continuation of a secondary structure, and therefore we are led to think that the cfx. and cpx. are two different structures, morphologically independent, though physiologically connected for performing their conductive functions. This independence

is visible to the eye in many instances where the two xylems are seen to run quite apart from one another for a great distance.

Wound structures are usually said to be primitive; if so, they are very instructive, for we have seen that the bundles thus influenced assume a concentric appearance and repeat the stages met with in the base of the petiole. We could then trace along either of these lines the history of the evolution of the foliar vascular tissue. Unfortunately the assumption is not yet proved as a general principle, and we are perhaps better inspired in explaining these abnormal structures as an attempt made by the plant to meet a physiological need.

As far as evidence from traumatic structures is concerned, the problem stands where we left it. Our final conclusions are therefore :—

The cfx. at the base is in great part a secondary growth, the cpx. is a primary structure; both are consequently independent morphologically. The two xylems overlap at their ends, are connected for a physiological function, and their reduced extremities point to a time when possibly they ran parallel throughout their whole course.

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6. *Variation of Structure and Colour of Flowers under Insolation.* *By* Colonel H. E. Rawson, *C.B.*, *R.E.*

This paper was a continuation of one communicated to Section K in 1908, entitled 'Colour Changes in Flowers produced by Controlling Insolation.' The same method has been followed throughout of shading off with a perfectly opaque screen all direct rays of the sun for certain selected intervals of daylight, while admitting all the diffuse light possible. In the conservatories the conditions have been those of ordinary domestication, an uralite roof to the lantern, with the shelves and framing being sufficient, together with the aspect of the buildings, to modify the sunlight as required. In the open garden vertical screens, in combination with others at a height and not necessarily overhead, but capable of being raised or lowered, sliding upon a fixed bar, and set horizontally or at any desired angle, have been adopted.

The garden nasturtium (*Tropæolum majus*) has continued to be used for the experiments, the history of each individual being carefully kept from the beginning in April 1905, but plants grown from English seed have been added for comparison with those from the seeds brought from South Africa. The same care has been taken as previously to keep all the conditions but those of exposure to direct sunlight the same, all the plants being looked after by one person and no fertilisers of any kind employed.

The new mauve variety obtained in Pretoria by the method of screening, whose seed was brought to England in 1907 and came true, now flowers and seeds freely in any aspect and amongst any other varieties. Three plants left behind with a friend and not screened at the selected intervals gave less and less seed each year until no seed matured, and in 1911 the variety became extinct there.

Sterility.—When any material change has been made in the colouring-pigments of the petals the flowers always show a marked tendency to be sterile. In one case only two seeds were obtained from forty-three flowers. Nothing abnormal may appear in the gynæceum, but the ovary does not develop and soon atrophies. Seeds of the mauve variety are now frequently of a purple colour, and the syncarpous gynæceum may consist of as many as five coherent carpels. On the other hand, the gynæceum is sometimes considerably modified, and in one case was apocarpous, four carpels being symmetrically arranged round a fifth in the centre, which pushed out a succession of ovaries until the whole was 10 mm. long. This plant was one of three which under somewhat similar conditions grew a secondary flower directly out of the seed of the first and developed a second seed therefrom. One of the latter seeds put out a small stalked leaf from a seam at the top, the blade of which was apparently designed to protect the base of the pistil from the full sun to which it was being exposed. On observing this the whole seed was enclosed in a calico bag, and it was the only one of the three to mature. In all three cases additional whorls of leaves appeared in the gynæceum so as to surround and cover the reproductive organs,

suggesting the development of a variety with double flowers for the first time from these plants.

Stem.—Strong evidence has been obtained of the existence during the colour-changes of a coupling between the colour of the stem and that of the subsequent flowers. In no case has a plant which has been grown from seed borne flowers of the mauve variety if any trace of red pigment has previously appeared in the stem, cotyledons, or foliage-leaves. Fasciation which did not occur in the earlier years is not infrequent now. The normal racemose inflorescence of the elongated main axis and of the branches has been much modified, the stalked leaves being suppressed altogether, or appearing in a very much reduced form upon the axis of the flower itself. The latter is now common in the case of the branches, and when the leaves are entirely suppressed it resembles a cymose inflorescence, in which each relatively main axis bears one lateral branch. On the main axis of the plant two stalked leaves and two axillary flowers will arise at the same node.

Plants of dwarf habit have appeared, though there were none originally. This character has been much studied. It has never been transmitted by the seed unless careful attention has been paid to the screening and a maximum amount of low sun afforded. Screened seedlings have now continued the habit for three generations, while unscreened from the same parent have reverted to climbers.

No difficulty has been experienced in keeping these annuals alive a second and third year, however much the colouring-pigments may have been changed. One plant is now in its fourth year. This recalls the fact that perennial varieties of the species are established and recognised.

Flowers.—A method has been devised by which the changes that the colouring-pigments undergo are recorded and reproduced by colour photography (*lantern slides*). This has enabled the effect of screening the same variety at different hours to be observed and the results to be classified. Markings on petals have been removed altogether, or, in other cases, intensified and enlarged so as to suffuse the whole face. Honey-guides have been removed.

Nothing has been done to prevent the mauve variety from fertilising or being fertilised by the other varieties, and it is probable that all now contain, though in a masked form, the colouring-pigments which go to make up the mauve colour. The latter is now to be seen in a large variety of shades. To produce modifications in any colouring-pigment it is not now necessary to screen the whole plant from the time the seedling appears. Each branch may be screened differently and slight but distinct colour-variations are obtained in the flowers. In one case where a plant was treated in this way, in an isolated bed, two new varieties were obtained in the following year from its self-sown seed. One of these bore simultaneously flowers varying from primrose to suffused rosy-fawn, many being cream splashed with rose. It was identified as a climbing variety of *Aurora* which is mentioned in Nicholson's Supplement, 1900, to 'Illustrated Dictionary of Gardening' as a recent introduction. A large number of plants is now annually obtained which are variable as to colour, and this variation is being transmitted through the seed. A salmon-pink with mauve patches has appeared, recalling a variety of *Antirrhinum majus* which sports in the same way. Four new varieties have appeared in 1913.

Structural Changes.—Besides those changes which have already been referred to, flowers with a short blunt spur (a recognised variety), or with none at all, or with two and three spurs, have become common, and are transmitted through the seed. Such flowers modify the petals, as many as six sessile petals or four sessile and two unguiculate arising instead of the normal two sessile and three unguiculate.

Sun's Altitude.—The experiments which have now extended over eight years definitely point to a connection between the variations of colour and structure and the sun's altitude, both seasonal and diurnal. Since January 1911 they have been followed with the microscope and the modifications noted, not only of the colouring-pigments contained in the cells, but of the forms of the epidermal papillary cells themselves.

There seems little room for doubt that by this method of screening, which departs but slightly from the conditions to be found in nature, metabolism has

been affected, and changes of colour and structure produced which can be reproduced in other individuals.

It is suggested that an explanation is to be found in the fact that solar rays of different refrangibility are transmitted through the atmosphere at different altitudes. Many instances have occurred of low sun modifying crimson colouring-pigments so that the yellow predominated, and of the highest sun available in these islands promoting the purple and violet pigments. Some red pigments, but not all, can be intensified by intermediate sun. Should these results be confirmed by independent investigators, they would afford a clue to many obscure problems of which correlated variation and variation under domestication may be specially mentioned.

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7. *Some Investigations in Anthocyan Formation.* *By* W. NEILSON JONES, *M.A.*

A series of papers dealing with the problems of pigmentation in plants have recently been published: the present paper is concerned with some points of special interest that have arisen in this work.[1]

1. Coloured petals of stocks, &c., soaked in 95 per cent. alcohol become colourless; transferred to water they regain their original colour.

It is believed that a pigment-producing mechanism and also a reducing body are present in the petals. The amount of water in the cells determines which way the pigment reaction shall go: in strong alcohol (95 per cent.) reduction occurs and the petals become colourless; in weak alcohol or water oxidation takes place, resulting in the production of pigment. It appears, further, that considerable quantities of reserve 'raw material' occur in some coloured flowers (*e.g.*, stock) from which pigment can be produced. The darkening of many flowers on fading is explicable on this hypothesis as being due to this 'raw material' coming into action.

2. *Benzidine* gives a blue colour with a solution of oxidase prepared from bran (bran+water+H_2O_2). *Methyl quinol* gives no reaction with this oxidase solution alone, but on the addition of a trace of *benzidine* becomes oxidised to a red colour. *Methyl quinol* thus behaves towards *benzidine* as an epistatic member of a colour series (*e.g.*, in *Primula sinensis*) to a hypostatic—that is, it is able to manifest itself only if the hypostatic member is present. (In this reaction the *benzidine* probably plays the part of a carrier of oxygen to the *methyl quinol.*)

Although it is dangerous to argue from analogy, in default of other evidence it would seem likely that the colours of an epistatic series were due to different substances behaving as *methyl quinol* above, rather than to the action of specific oxidases.

MONDAY, SEPTEMBER 15.

The following Papers were read:—

1. *The Development of the Apothecium in the Lichen Peltigera.* *By* O. V. DARBISHIRE.

Pycnidospores, or spermatia, are very rare indeed in this genus, and their occurrence seems to be confined to a few species, and is even here very rare. Yet we find that in certain species apothecia are formed in great numbers. Fuenfstueck and Baur have examined *Peltigera,* and without going into nuclear details the latter described it as a case of apogamy.

The following additional details have been made out. Growth of the vegetative thallus is mainly marginal, though new hyphæ may be intercalated between the old upright hyphæ of the cortex. It is amongst the young marginal hyphæ that we find the beginning of the fruit. Certain cells of the medullary

[1] F. Keeble, E. Frankland Armstrong, W. Neilson Jones. *The Formation of Anthocyan Pigments in Plants,* Parts iv. and vi.

hyphæ, which may be followed out some distance back into the older parts of the thallus, swell up and stain more deeply than the others. They are at first uninuclear, but soon become multinuclear as they increase in size. Fusions with neighbouring cells are common, but no transference of nuclei has been observed. Soon we get a mass of closely interwoven cells full of cytoplasm and containing numerous nuclei. No coiled carpogonia can be made out, but taken as a whole these darkly stained cells can be seen to form part of a connected system of branched hyphæ coming from the medulla further back, and passing into the cortical margin. The multinuclear condition seems to be due to simultaneous nuclear divisions in the cells, and not to any passage of nuclei from cell to cell. When nuclear division is still active, long unbranched but multicellular hyphæ can be seen to grow out towards the cortex, forcing their way through the latter generally at an oblique angle. These are from structure and appearance functionless trichogynes. They gradually disappear. Certain of the large cells—the 'ascogonia'—now grow out, and the nuclei formed by simultaneous division—that is to say, female nuclei—pass into the ascogenous hyphæ, thus formed, in pairs. From these the asci appear to derive their first nucleus in the usual way.

2. *The Structure and Life-history of* Verrucaria margaracea, *an Aquatic Lichen. By* Miss E. M. Poulton, *M.Sc.*

The thallus is a small, more or less circular disc, attached to pebbles at the bottom of streams. It is very thin, and its morphological characters change with advancing age. It was found that the ascospores were unseptate, uniseptate, biseptate, or triseptate, depending upon their maturity. They could, however, germinate in any of these states. They invariably germinated *en masse* while within the perithecium, the tuft of entangled hyphæ thus produced being expelled through the ostiole and forming an admirable device for catching the Algal cells floating in the water.

3. *The Biology of the Apple Canker Fungus,* Nectria ditissima, *Tul. By* S. P. Wiltshire.

Nectria ditissima is a genuine wound parasite. The normal reaction of the cortex to injury is the formation of a phellogen layer over the exposed area, and so inoculations can only be successful when the injury is deep enough for the fungus to reach the wood; otherwise the diseased portion is surrounded by the phellogen, the tree thus healing itself of the disease.

The fungus travels across the cortex through the intercellular spaces, across the phloem and cambium by mechanically breaking through the cell walls (disintegration of the tissue soon following), and then traverses the woody elements and pith through the pits in the walls. The medullary rays do not form a special means of entrance to the wood.

The reactions of the host against the disease are the formation of

(1) Phellogen, at the limits of the infected region in the cortex;

(2) Abnormal wood of cells very similar to those of the medullary rays, and containing 'gum sacs';

(3) Wound gum in the wood vessels—which substance, however, can be penetrated by the hyphæ.

The mycelium may possibly be able to travel about the stem and break out to form a fresh canker, but such is probably abnormal, the extent of the hyphæ usually remaining quite local. No trace of an invisible hibernating mycelium has been found in apparently healthy shoots.

The chief means of inoculation in nature are injuries made by (1) frost; (2) *Schizoneura lanigera*—the woolly aphis. In both cases the bark is burst by the swelling of various tissues.

The relatively immune varieties of apple readily infect if inoculated through suitable injuries. Investigations into the thickness of the bark, the rate of reaction to injury, and the growing power of the fungus in the sap have given negative results, suggesting that the determining factor is physiological.

4. *Conditions necessary for the Germination of the Spores of* Coprinus sterquilinus, *Fr. By* M. L. Baden.

Many workers have experienced a difficulty in germinating the spores of various species of coprophilous Ascomycetes and Basidiomycetes, in some cases it being found impossible to germinate them at all in nutrient solutions. The same difficulty had to be contended with in the case of *Coprinus sterquilinus* Fr., growing on horse-dung. Attempts were made to germinate the spores in various solutions of different strengths, acidity, &c., for several weeks without success. Eventually vigorous germination occurred in one particular solution, but it was found, on staining, that numerous bacteria were present. Hanging-drop cultures of the spores in media with and without the bacteria were therefore made, and in every case it was found that the spores germinated at once in the cultures with bacteria, but never at all in those without. This led to the conclusion that in some way the bacteria are necessary for the germination of the spores of *Coprinus sterquilinus* Fr. The connection between the bacteria and the spores seems to continue for some time after the commencement of germination, since the bacteria completely cover the mycelium at certain points, particularly where branching occurs. In exactly what way the bacteria are of benefit to the spores it is not possible to say, but the following suggestions are made. The bacteria may produce certain substances which react on the spores in such a way as to soften the wall and thereby make germination possible. Schmidt found that certain chemical reagents were necessary for germination at temperatures above 40° C. It is not unlikely that the bacteria produce the same effect as the reagents, which may even be a product of the bacteria themselves. On the other hand, the bacteria may remove any by-products which happen to be produced by the fungus, germination being impossible while such are present. Since various bacteria are always present in the alimentary canal of animals, it is quite feasible that there should be some connection between them and the spores, and that the two should aid one another.

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5. *The Organisation of the Hymenium in the Genus Coprinus. By* Professor A. H. Reginald Buller.

1. Most species of Coprinus have four sports on each basidium, but in *Coprinus bisporiga* Buller (as yet undescribed) the basidia usually have two spores each, and but rarely one. No three- or four-spored basidia have been observed in this species. In *C. narcoticus* most of the basidia are normally trisporigous, but a few occasional ones are quadrisporigous. *Coprinus narcoticus* is the only trisporigous Hymenomycete known to the author.

2. In Coprinus (neglecting the cystidia which are present in some species and absent in others), the hymenium consists of fertile basidia and sterile paraphyses. The latter are useful as spacial agents, in that they prevent the spores on adjacent simultaneously maturing basidia from touching one another.

3. In most species of Coprinus the basidia are *dimorphic*. Long, obviously protuberant, basidia and short, practically non-protuberant, basidia are interspersed among one another, so as to form a mosaic-work which is of such a kind that the spores of the long basidia are further from the surface of the hymenium than the spores of the short basidia, and so that they frequently overlap the latter without touching them. The dimorphism of the basidia permits of a closer packing of the basidia on the hymenium than would otherwise be possible. Hymenial space is thus economised for spore production. In the zone of spore discharge, which proceeds upwards on each gill, the long basidia discharge their spores a short time before the immediately adjacent short basidia. The spores of the short basidia, at the time when they are shot out into the interlamellar spaces, are thus prevented from colliding with the spores of the longer basidia. In *Coprinus micaceus* the basidia are *quadrimorphic*.

4. The dimorphism of the basidia in the genus Coprinus was discovered by the author after the publication of his 'Researches on Fungi' in 1909. A short account of the phenomenon was given in the Transactions of the British Myco-

logical Society in 1911, but without illustrations. The present paper was accompanied with a full set of illustrations, which the author hopes to publish in 1914 in an additional volume of his 'Researches on Fungi.'

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6. *The Structure, Life-history, and Systematic Position of the Genus Microspora. By* Professor G. S. WEST, *M.A., D.Sc.*

Although various species of *Microspora* are amongst the commonest of Green Algæ, their structure and life-histories have been very imperfectly known, a state of affairs which has resulted in much controversy regarding the systematic position of the genus. The published accounts of the cytology of the genus are in general very defective. In *M. tumidula* and one or two others the cell-wall becomes disarticulated into H-pieces on the liberation of the zoogonidia or on the death and decay of the filament. In *M. stagnorum* and others the cell-wall never breaks in this manner. The chloroplast is a reticulum of variable character, but with the exception of *M. stagnorum* is fairly constant for each species. Pyrenoids do not occur.

The zoogonidia were biciliated in all the cases observed, and arose singly from the vegetative cells. In *M. tumidula* they are liberated by the dissociation of the entire filament into H-pieces, but in *M. stagnorum* their liberation is brought about by the rapid conversion into mucilage of the lateral walls. Various conditions intermediate between these two types of zoospore-liberation are found in other species.

Aplanospores and akinetes are formed in most species, the akinetes of *M. floccosa* being the most frequently met with. If kept in water these akinetes were found to undergo no change for a period of two years, but if dried for a few weeks and then placed in water they very soon germinated, growing directly into a new *Microspora*-filament.

No gametes were observed in any of the species.

A careful consideration of the characters of the various species indicates that *Microspora* is best placed in a separate family, the Microsporaceæ, of the Ulotrichales.

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7. Zygnema ericetorum *and its Position in the Zygnemaceæ. By* Professor G. S. WEST, *M.A., D.Sc., and* Miss C. B. STARKEY, *M.Sc.*

A careful cytological examination of specimens of this Alga from various localities reveals the fact that the chromatophores have been incorrectly described. There is only one chloroplast in each cell, remarkable for its comparatively entire margin. It is deeply constricted in the middle, and the nucleus reposes in the constriction. One conspicuous pyrenoid is present in each half of the chloroplast, which may sometimes be twisted through 180° at the point of constriction. Cells with two chloroplasts are unusual and generally abnormal.

A cytological examination of *Zygnema pachydermum*, described in 1894 from the West Indies, shows that vegetatively this Alga is identical with *Z. ericetorum,* and moreover its conjugation is quite normal as in other species of *Zygnema.* Hence, it appears highly probable that the genus *Zygogonium* as upheld by De Bary (1858), Wille (1909), and others, is based upon an error, since the conjugated specimens of '*Zygogonium didymum*' (= *Zygnema ericetorum*) figured by De Bary are very likely monstrous forms.

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8. *Evidence which shows that Mutation and Mendelian Splitting are Different Processes. By* Dr. R. RUGGLES GATES.

Definite evidence has been obtained showing that some at least of the mutations of Œnothera are not due to recombinations of Mendelian characters, as various writers have assumed, but to irregularities in meiosis, which lead to changes in nuclear structure. The cases of *Œ. lata* and *Œ. semilata* only will be referred to in this paper, because they offer a means of differentiating between characters which are inherited from the parents and those which arise as

a result of unequal or irregular chromosome distribution during meiosis. Miss Lutz and myself have independently shown that the mutant *lata* possesses 15 chromosomes instead of 14, and with the valuable help of Miss Nesta Thomas I have recently shown that the same is true of *semilata*. We have since found that all individuals possessing the foliage and habit of *lata* or *semilata* contain 15 chromosomes, even when these characters are associated with others derived by inheritance from their parental forms.

Thus, in a mutating race of *Œ. biennis* from Madrid, one mutant was *Œ. lata biennis*, having *lata* foliage and *biennis* flowers. This plant has 15 chromosomes, and must have originated through a meiotic irregularity. Again in the F_2 of *Œ. rubricalyx* × *Œ. grandiflora* two individuals appeared in one family, having *lata* foliage and habit combined with *rubricalyx* pigmentation. This *lata rubricalyx* type also has 15 chromosomes, showing that in addition to the characters derived by inheritance from the cross, the *lata* foliage appears whenever the fertilised egg contains 15 chromosomes.

Such instances show definitely that mutation is a process which is independent of the recombinations of characters such as occur in hybrids.

The source of the 15 chromosomes was shown several years ago to lie in occasional irregularities in the distribution of the chromosomes during reduction. In such cases, two pollen grains of a pollen tetrad receive eight chromosomes, and the other two receive six. When an egg having seven chromosomes is fertilised by a male cell from a pollen grain with eight, the resulting individual will have 15 chromosomes and the foliage of *lata* or *semilata*.

The extra chromosome, which is a triplicate of a pair already present, is thus associated with the development of certain foliage characters in Œnothera in the same way that the accessory chromosome, when present in duplicate is, in certain insects, associated with the development of female sex characters. This is apparently the first case in plants in which a definite relation has been shown to exist between a chromosome and particular external characters.

The extra chromosome in Œnothera sometimes changes its behaviour in meiosis, dividing in the first instead of the second meiotic division. The same thing sometimes happens to one of the ordinary chromosomes.

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9. *Epiphyllous Vegetation.* By Professor W. H. Lang, *F.R.S.*

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10. *The Preservation of the British Flora.* By A. R. Horwood.

So urgent has this matter become that it is important that the Botanical Section of this Association should discuss the question with a view to the possibility of taking some preventive steps. A committee of the Association was appointed for this purpose, and reported in 1886 and subsequently on the subject. The question then turned upon the prevalence of hawking and collecting, and the results. The *raison d'être* of the present communication is entirely different, the facts upon which it is based, derived from all parts of the British Isles, being then unknown. Whilst this factor is even greater to-day, there are indeed other causes at work on a widespread scale, which demand the attention of all botanists, as they seriously affect that new and increasingly important branch of botany, ecology. At the same time, any causes affecting the status of species will be viewed with apprehension by those who study systematic botany.

Briefly there are certain natural or artificial factors that are difficult to control except in special ways, and it is to solve these, and to elicit some information as to the extent of their effect, that this subject is introduced.

It is established that drought now recurs in cycles. During 1911 several instances of the extermination of plants were communicated to the author, and others were personally noted. If they are to be expected every few years some steps should be taken to prevent their effect being disastrous. Montane and ericetal species are particularly susceptible. Bog-pools are also liable to be completely dried up.

Drainage is a great factor in disturbing the natural vegetation of the country. A single instance, the Fens, suffices to show how great such an effect

can be. Fortunately some parts of it remain to show the special type of vegetation, but these are disappearing. Peat-cutting in Ireland has an effect of much the same nature, and thereby bogs are turned into tussocky pasture of *Juncetum communis* type.

Cultivation following tree-felling and drainage has produced the prevalent mesophytic vegetation of the Midlands and elsewhere. Tree-felling has been influential in converting the country entirely from natural woodland to artificial meadows and pasture. Forestry has been much neglected in the past, and apart from the effect on the moisture of a district, the neglect to plant trees where they are cut, except where afforestation associations exist, destroys the natural ground flora.

Golf links are extremely detrimental to those plants that only grow on sand-dunes and contiguous tracts along the coast, limited in area, and also inland heaths, now few in number.

It is suggested that in every case where such causes (only a few have been mentioned) are at work, an endeavour should be made to obtain in the case of an association of plants, a reservation, and in that of a single station for a rare plant, some adequate means of protection. The author, as Recorder of the Plant Protection Section of the Selborne Society, will be glad to receive information and advice thereupon.

TUESDAY, SEPTEMBER 16.

The following Papers and Reports were read :—

1. *Notes on* Stellaria graminea. *By* A. S. Horne, *B.Sc.*, *F.G.S.*

These notes related to variability in the flower of *Stellaria graminea* collected in Surrey and by the kindness of Dr. Moss in the Fen near Abbot's Repton.

The diameter of the corolla in flowers belonging to individual plants, in *S. graminea,* may measure 4 mm., 15 mm., or intermediate lengths; whereas it exceeds 20 mm. in *S. palustris.*

The width of the petal-segments may reach ·5 mm., 2 mm., or intermediate measurements in *S. graminea,* but exceeds 2 mm., and may reach 4 mm., in *S. palustris.*

The stamens may be all very short (less than $\frac{1}{3}$ sepals) and sterile, or all long (exceeding the sepals) and fertile, or of several intermediate types in *S. graminea.*

The correlation between the above-mentioned characters was explained by means of a table.

With the assistance of Mr. E. C. Titschmarsh, of the R.H.S. School of Horticulture, certain plants were treated experimentally (transplanted, propagated vegetatively, and seedlings raised).

In one experiment, the flowers of a plant called B, 14·5 mm.-15 mm. cor. diam., 1 mm.-1·2 mm. cor. lobe, and stamens longest type, in several cultures, after nineteen days changed to 6·4 mm. cor. diam., ·7 mm. cor. lobe, with stamens correspondingly reduced in size; whilst another form, A, 9 mm. cor. diam., 1 mm. cor. lobe, and stamens of an intermediate type ($\frac{2}{3}$ sepals), remained unchanged. The experimentally produced flowers of the B plant approximate closely to those of very small flowered plants in Nature, such as 4 mm. cor. diam., ·7 mm. cor. lobe, with stamens $\frac{1}{2}$ sepals, and male sterile plants, such as 6·5 cor. diam., ·8 cor. lobe (stamens less than $\frac{1}{3}$ sepals).

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2. *A Botanical Survey of the Maritime Plant-formations at Holme, Norfolk. By* P. H. Allen, *B.A.*

Last June, at the suggestion of Mr. C. E. Moss, a small party was organised at the Cambridge University Botany School to commence a detailed botanical survey of the maritime vegetation at Holme, in the north-west of

Norfolk. The area chosen for the survey has been visited by parties from the Cambridge Botany School on many occasions during the last six years. It lies on the south-eastern shore of the Wash.

The principal feature of the area is a sandy salt marsh, with considerable quantities of *Statice Limonium*, **S. bineurosum*, **S. bellidifolium*, **Salicornia perennis* var. *radicans*, *S. disarticulata*, *Armeria maritima*, *Atriplex portulacoides*, and other halophytes. Fixed dunes with *Ammophila arenaria* limit the salt marsh on three sides; and embryonic dunes with *Agropyron junceum* and *Elymus arenarius* occur. Along the seaward side of the area is a system of shingle banks, with well-developed lateral banks and apposition banks. The lateral banks are characterised by **Suæda fruticosa* and **Frankenia lævis*. The species here preceded by an asterisk are Mediterranean plants which in this locality reach their northern limit. A considerable extent of bare sand also occurs, and this is locally beginning to show signs of being colonised by *Suæda maritima*. The sea enters the salt marsh through a small break in the shingle bank. At ordinary high tides most of the bare sands are covered, but in the salt marsh itself only the channels are filled.

The members of the party numbered six. In June they were able to spend a few days at Holme, and they commenced work on a fairly large scale, and the intention is to carry on the work later in the year and in succeeding years.

The mapping out of the area was begun by chaining out a base-line from one end to the other. It was seven furlongs in length. At each furlong offsets were chained out, on the landward side to the edge of the cultivated land and on the seaward side to the low-water line. The filling in of the detail in the areas between the offsets was commenced with the plain table on a scale of eighty inches to the mile (1 : 792). On this scale, neglecting the bare sand towards the even tide-line, the map commenced consists of fourteen sheets, each about ten inches square. On these sheets, of which only one is as yet completed, the different plant associations and societies are shown in different columns. In addition to the mapping, levels were taken at most of the furlong points on the base-line, the level being brought in from a beach bank in Holme. Elevations have also been plotted along two of the offset lines from the edge of cultivation to the low-water mark.

In order to complete the map and the series of elevations across both ends of the area, across at each furlong stake and along the base-line, arrangements were made for a party to go to Holme during the present month (September). Work on the analysis of the soil and soil-water were then to be commenced. It is hoped that by these means light may be thrown on some of the problems of plant distribution which are presented by the salt marsh, the sand dunes, and the shingle banks. Looking still further ahead, a detailed record of the succession of changes occurring over the area will also be obtained.

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3. *On the Distribution of* Suæda fruticosa *and its rôle in the Stabilising of Active Shingle. By* Professor F. W. Oliver, *F.R.S.*

Shingle beaches exposed to the sea are liable to landward travel when very high tides are accompanied by onshore gales. To some extent all shingle plants retard or modify this movement, but *Suæda fruticosa*, from its shrubby habit of growth and high capacity of rejuvenescence, is the most effective stabiliser of all British shingle plants.

The present communication dealt with the conditions of establishment of this plant, and with the manner in which it promotes the fixation of active shingle.

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4. *The Influence of River Development on Plant Distribution. By* A. R. Horwood.

Little attention has been drawn to the influence of rivers on plant dispersal.

Primarily plants depend upon soil, altitude, and climate for their distribution or occurrence in natural plant formations.

Now, in an area where the 'solid' rocks are entirely or largely covered by

glacial boulder clay, this development is of great importance, for if the streams had not cut their way down to the solid rocks below, and deposited alluvium, &c., in their course, the flora would have been much more uniform.

In Leicestershire, for instance, the consequents or dip-streams flow from the north-west to the south-east, with the dip (originally entirely). They give rise to a series of parallel valleys, with intervening hills, developing lower lias each side of their course, on each side of patches of alluvium. The later strike stream or subsequent of the River Soar (in the first part of its course) was developed along a line of outcrop, and captured the streams to the east, so causing them to flow to the west, and cut back their bed towards the divide formed by the high escarpment of the Middle Lias and Oolites of East Leicestershire. River development thus depends largely on the junction of soft and hard strata, and this again leads to diversity in the natural habitats for plants. Streams also have a radial arrangement subsidiary to this, thus complicating the outcrop conformation. Moreover, the little obsequents with laterals cut back like strike streams are like the multifid lobes and saddles of the suture of an Ammonite, and it would be extremely difficult to map the plants found on such irregular formations except by choosing the actual geological formations on which they occur as a basis. But as altitude also enters to some extent into the effect of river development (since some valleys are very deep), and there is the influence on the soil by the action of the river on the *area* of each soil, there is something to be said for the retention, for floristic purposes, of the old hydrographical districts adopted in some floras, for they serve as (i) an indication of the effect of some one stream or river in the district in developing the soil and controlling plant dispersal, and (ii) as a ready means of referring to the area, by a process of subdivision, for the station of a plant, but it is admitted that this is an entirely artificial advantage.

For ecological purposes these divisions are of no use, as a description of the district should be by the natural plant formations. The contour formed by the outcrop of each formation can readily be defined in the valleys cut through by streams, except where denudation has obscured them.

The flora of the boulder clay is composite, and though certain differences can be noted between the different types it includes, it is, as a whole, commonplace. That of such a formation as the Lower Lias can be distinguished, and even made use of, to determine the junction between the outcrops of the two.

The slope, aspect, and relative moisture, &c., imposed on a valley by river development have also all an effect on plant distribution.

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5. *Some Features of the Sand-dunes in the S.W. Corner of Anglesey.* *By* W. H. Wortham.

The sand-dunes in the S.W. corner of Anglesey form a spit of about five miles in area, bounded to N.W. and to S.E. by river estuary and strait respectively, and to the S.W. by open sea; the sand is aggregated about a high spit of schistose rock, often over 100 feet high, which forms a backbone running from S.W. to N.E.; parts of it are uncovered by sand. The fixed dune association, where the sand forms a thin covering over the summits of the schistose rocks, is a *Caricetum arenariæ*, which forms a close sward.

The region to the N.W. of this ridge, owing to the frequent rebound of wind-driven sand from the ridge, is occupied entirely by white dunes, of which the only colonist is marram grass, alternating with embryonic stages of *Salix repens* marsh. These dunes are increasing in extent.

The dunes to the S.E. of the ridge are stationary in extent, and wind-destruction is marked. The marram of the white dunes here shows associates, of which *Euphorbia paralias* is the first. Salix dunes are here extensive, and have a twofold origin: (1) The inundation of a dune-marsh with sand, a process which results in the extinction of all but the *Salix repens*, which grows up through the sand, forming low dunes; (2) the invasion of a stretch of white, or even grey, dune by salix seedlings, often from a distance, which grow up, collect blown sand round them, and form dunes in exactly the same way as marram. Wind-action is destroying these salix dunes in many places, and blow-outs,

exposing over 16 feet of vertically growing roots, may be found. Salix marsh is well developed on the S.E. side.

The ultimate associations are, for the *Salix repens* marsh Calluna heath, for the dune associations grass heath with *Agrostis vulgaris* dominant; the *Caricetum arenariæ* of the summits is probably a facies of the latter association.

6. *Report on the Structure of Fossil Plants.*

7. *Report on the Investigation of the Jurassic Flora of Yorkshire.* See Reports, p. 264.

8. *Interim Report on the Investigation of the Flora of the Peat of the Kennet Valley.*—See Reports, p. 265.

9. *Interim Report on the Investigation of the Vegetation of Ditcham Park, Hampshire.*—See Reports, p. 266.

10. *Report on the Registration of Negatives of Botanical Photographs.* See Reports, p. 267.

Joint Meeting with Sections D and I.—See p. 527.

Section L.—EDUCATIONAL SCIENCE.

President of the Section.—Principal E. H. Griffiths, Sc.D., LL.D., F.R.S.

THURSDAY, SEPTEMBER 11.

The President delivered the following Address:—

Some two thousand years ago an aged philosopher said that there were only three things he regretted; the first was that he had wasted a day of his life, the second that he had travelled by sea when he might have gone by land, and the third that he had told a secret to his wife. My own regrets are of a very different nature, for, as regards the first of those advanced by Cato, one day would count for little in my wastage, and with the second and third complaints I have no sympathy. I have, however, a regret greater than any of these—namely, that I accepted the honour of being the President of this Section, inasmuch as that acceptance has involved the necessity of a Presidential Address.

When I glance at the list of distinguished men who have been my predecessors in this chair, I appreciate more fully both the difficulty of the task and the deficiencies of the operator. These difficulties are not diminished by the reflection that in speaking on Education one is not addressing a comparatively small audience of those interested in some definite branch of Science, but that the speaker has to deal with a subject on which almost every adult inhabitant of this kingdom regards himself as an authority.

I may illustrate the popular attitude by relating a conversation overheard in a tramcar in one of our cities at the time of the passing of the Education Act of 1902. One of the passengers remarked that many men, who on the School Board had interested themselves in educational matters, would now cease to be members of the Education Authority, and he asked: 'Who is there on the City Council who has real knowledge of the subject?' 'Oh,' replied his companion, 'that's all right. Councillor X. has been reading up the subject for the last month!'

I am also aware that he who ventures to express publicly his real feelings on educational matters is deliberately sailing into troubled waters, for, with the Scylla of sectarianism on the one side and the Charybdis of political partisanship on the other, it is difficult to steer a safe course.

I would ask you, unpleasant though the effort may be, to recall the days when the Bill of 1902 was discussed in the House of Commons. In those days and weeks of dreary discussion it would not be easy for an anxious inquirer to find any debate on a topic really educational. The feelings of the general public were, it seems to me, admirably summarised by Mr. Godley in verses from which I cannot resist the temptation of giving a quotation:—

'Essence of boredom! stupefying theme!
Whereon with eloquence less deep than full,
Still maundering on with slow continuous stream,
All can expatiate and all be dull.

Bane of the mind and topic of debate,
That drugs the reader to a restless doze,
Thou that with soul-annihilating weight
Crushest the bard and hypnotises those
Who plod the placid path of plain pedestrian prose.'

To me the concluding verse appeals with special force :—

'From scenes like these my Muse would fain withdraw;
To Taff's still valley be my footsteps led,
Where happy Unions 'neath the shield of Law
Heave bricks bisected at the blackleg's head;
In those calm shades my desultory oat
Of taxed land values shall contented trill
Of man ennobled by a single vote;
In short, I'll sing of anything you will,
Except of thee alone, oh! Education Bill.'

Nevertheless, it is my duty to-day to address you on educational matters, and my object is not so much to put before you views of my own, which would come with slight authority and carry little weight, but to venture to present the opinions of others and to inquire how far such general impressions are justified. I should add that I limit the inquiry to the area affected by the Education Act of 1902, that is, to England and Wales.

We have now had forty years' experience of compulsory education, and more than ten years' experience of the working of the Education Act of 1902. We are spending at the present time out of the rates and taxes about thirty-four millions per annum upon education. It seems reasonable, as a nation of shopkeepers, that we should ask if we are getting value for our money, and the reply will, of course, depend on what we mean by value, for the man in the counting-house, the man in the street, and the man in the schoolroom all have different standards of valuation.

Some of us are old enough to contrast the position of to-day with that of forty years ago. Do we observe any definite advance in knowledge, intelligence, character, or manners, as compared with the pre-compulsory days? We must all be aware of the tendency to magnify the past at the expense of the present, but, after making due allowance for the fact that 'the past seems best, things present ever worst,' it appears difficult to find distinct evidence of improvement in any way commensurate with the sacrifices which have been made.

I have taken every opportunity of ascertaining the views of men of varied occupations and differing social positions upon this matter, and I confess that the impression received is one of universal discontent. The complaints are not only of want of knowledge, but also, which is far more serious, of want of intelligence. Consider a trivial example drawn from my own experience. I am a motorist in a small way. My ambition has been restricted in the matter of chauffeurs to lads fresh from our elementary schools, whom I have employed for what I may summarise as washing and greasing purposes. Some six or seven of such lads have passed through my hands during the past nine years, and all of them have been at a primary school for some seven or eight years. They came with good characters, and all had passed up to the fifth or sixth standard. None of them could spell correctly, keep simple accounts, or appear to derive any enjoyment from reading. Nevertheless, two of them, at all events, gave evidence of a real liking for mechanics, and within a year or so could be trusted to take the engines to pieces, clean them, and replace them with but little supervision. It might be argued that although they had imperfectly acquired the rudiments of 'the three R's,' the aptitude of these lads was the result of their training. Of this, however, I could find no evidence. It is difficult to understand how these boys could have profited so little by their many years of school life. If such an example is in any way typical, it is time to consider what the country is obtaining in return for the thirty millions annually expended on elementary education alone.

It may be thought that I have been unfortunate in my experience. I do not,

however, believe that my case *is* singular. In the *Contemporary Review* for July 1909 Professor Stanley Jevons contributed an article on 'The Causes of Unemployment.' He referred therein to the opportunities afforded him by University Settlement Boys' Clubs in London and Cardiff of forming a judgment concerning the products of our primary schools. He described the following experiment :—

'I arranged to test a few members of the Boys' Club. They were gathered in a room with pens and paper and were asked to write down the following short sentence, which was spoken to them distinctly twice, as an example of the kind of message which they might be expected to have to write occasionally for an employer : "I have not been able to find the book which you sent me to fetch." The test was one both of memory and spelling, and most of the boys failed in one or both respects.'

Professor Jevons gave facsimiles of the results, which I am unable to reproduce; but I can indicate the nature of the spelling. It will be noticed that there are no words of two syllables. The following is the best of the batch :—

Boy aged nearly sixteen : 'I cannot (fetch) find the book which you sent me to fetch.'

The following are from boys aged fourteen and fifteen respectively :—

'I have not been *abele* to find the *boock whi witch* I sent you (for) to *fitch*.

'I have Not *bend* able to find the book *With* I sent you to *fath*.'

All these boys have been through one of our large primary schools.

Professor Jevons added : 'In contemplating the question of unemployment one is at once led to the conclusion to which so many other economic problems ultimately lead—that the only certain means of abating the evil is the improvement of the individual.'

Passing from such limited experiences to the views of those who are brought into contact with the products in bulk, a sense of dissatisfaction and uneasiness is no less evident. Consider the following extracts from the Presidential Address of Mr. Walter Dixon, M.I.M.E., to the West of Scotland Iron and Steel Institute in October last :—

'I have, over a somewhat extended period and a wide area, made inquiries amongst those who have the control of about 200,000 men in our own allied industries, with the following results :—

'It is the unanimous opinion that any book-learning outside the rudiments of "the three R's" is considered a matter outside the requirements of the education of more than 90 per cent. of the usual manual workers. In other words, the work that these men are called upon to do, the labour which they have to perform in their daily avocation, would be as efficient, as successful, and as expeditiously performed if the men had no school education whatever outside "the three R's."'

If there is any truth in this severe indictment there is small cause for wonder if a general sense of uneasiness exists amongst those who consider that the future prosperity and safety of this country are dependent on the manner in which we train the rising generation.

In justice to Mr. Dixon I must give a further extract from his Address :—

'During the recent meeting of the British Association in Dundee I spent some time amongst Educational Authorities, not only those belonging to our own country, but delegates from other nations, and I find that they themselves are beginning to see the futility of the present methods and to realise that they are ploughing the sands. Amongst other matters, it was of interest to note that they are at present promulgating a scheme for what they call vocational education. In other words, I gather that they are now attempting in a modified way to replace the old 'prentice system by teaching trades in their schools, so that children may enter the trades as skilled workers—a system which, to my mind, would render the present confusion more confounded. . . . We must recognise that the mechanical developments of the last half-century have done away in a large measure with the possibility of the interest which a man could once take

in his daily work, inasmuch that few men now make anything, but only a *small portion of something*. A statement was made at Dundee that 135 different persons were employed in the making of a boot. It is not to be expected that any of these 135 workers can get enthusiastic about their particular bit. We must recognise that as long as we live under the reign of industrial competition the hours of labour are likely to be hours of stress, and that when a man has finished his labour it is only right, it is only human, that he should have hours of reasonable recreation. It is with a view of making these hours of recreation worthy of the nation to which we belong that I feel that our educational methods might, and ultimately will, be altered and rendered valuable.'

If I may venture to summarise Mr. Dixon's Address as a whole, it appears to me that the argument is somewhat as follows: It is admitted that 'the three R's' are necessary for all workers, of whatever grade, almost as necessary for the mental as are sight and hearing for the physical equipment. A large majority of manual labourers, however, are not rendered any more efficient in the discharge of their tasks by further instruction of an academic character, and therefore we should aim at providing them with some form of education which would so quicken their intelligence as to enable them to find an interest in matters external to their employment and thus lead them to utilise their hours of recreation in a sane and healthy manner. It should be our object not so much to train all our soldiers as if they were to be generals, as to give them that education which would make them good soldiers, and to spare no expenditure of time or money in the further education and development of the small percentage who have shown those qualities which lead, under proper guidance, to high achievement.

The assumption that all children are fitted to profit by more than the rudiments of academic education is, I believe, responsible for many of our present difficulties. In physical matters we seem to be wiser. We take account of bodily disabilities; we do not train lame men for racing, or enter carthorses for the Derby; we do not accept the short-sighted or the colour-blind as sailors; but those who talk of compulsory further education appear to think that all men are on an equality as regards mental equipment. Democracy in its control of education counts noses rather than brains. I observe, for example, that the Education Committees, on which I have, or have had, the honour of serving, are unwilling to continue those higher technical classes in science in which the numbers are necessarily small. A class of four in higher mathematics will probably be discontinued, whereas a class of one hundred in shorthand will be regarded as a highly successful achievement.

Such Education Committees, however, are only carrying out what is apparently the policy of those sitting in the seats of authority. A nation which expends but four millions for the encouragement of higher education and research and thirty millions on the rudiments cannot be said to lend that recognition, assistance, and encouragement to the best brains of the country which is the one form of educational outlay which is certain to bring, as Mr. Wells has truly indicated, not only the best return industrially, but also an immunity from invasion otherwise unobtainable.

It is possible that the views taken by Mr. Dixon and the employers and business men whose opinions I have attempted to gather are unduly pessimistic. I have, therefore, turned naturally to the teachers, with many of whom I am brought into contact.

I find, on the whole, much the same spirit of pessimism prevailing. I can only recollect one gentleman—a teacher of long experience and high standing—who takes a brighter view of the position. According to him, the children leave our schools better instructed, more intelligent, and better mannered than was the case some twenty years ago.

It is true that teachers as a body agree that there has been one real advance—viz. the abolition of the system of payment by results—but many of them admit that during the past ten years progress, if any, has been slight. They plead in extenuation that the large size of the classes is in itself a barrier to real efficiency, and that the teacher is so fettered by regulations, so bothered by the fads of individual Inspectors, that we ought to be gratified, rather than disappointed, by the results achieved. It is a significant fact that the supply of teachers for our primary schools is diminishing, and that, as a necessary consequence, the

proportion of fully trained and qualified teachers, although increasing, is unduly small. The attractions of the profession are undoubtedly insufficient. When we consider the meagre salaries, the slow, very slow, promotion, the few prizes and the slight social recognition, it is a surprising fact that so many able men and women are prepared to accept the lot of teachers in our primary schools.

The teaching profession, if profession it can rightly be called, compares unfavourably with the so-called learned professions. It is noticeable that but few of our primary school teachers are prominent in civic affairs. Their representation on Education Committees, for example, is quite inadequate; during the discharge of their duties they are unable to mix with their fellow-citizens, and thus gain experience in the same manner as the clergyman, the doctor, or the solicitor. The regulations practically forbid participation in public life, and the teachers' activities are regarded as bounded by the walls of the schoolroom.

If the results of our educational system are disappointing, it is not for us to throw the blame on the teachers. Until we learn that satisfactory results can be obtained only when the life and emoluments of the schoolmaster are such as to offer avenues to distinction comparable with those of the learned professions, we cannot hope to attract into what should be, after all, the most important of all professions, the best brains and energies of the community.[1]

Undoubtedly, however, we *have* made advances within the last generation. Our outlook is different, but we are expecting higher achievement without affording that inducement which entitles us to demand it. Our industrial needs have impressed upon us the necessity of a wider view of the meaning of the word 'education.' We are slowly learning that we should aim at the awakening of the intelligence, rather than at the mere imparting of knowledge by what I might term force-pump methods. Forcible feeding is not proving a success either physically or mentally.

Some fifty years ago a leading name in the educational world was that of Todhunter—a name which I admit was regarded with terror rather than affection by many of us in our school days. As a correction to pessimism I venture to inflict upon you the following extract from Todhunter's 'Conflict of Studies,' published in 1873:—

'It may be said that the fact makes a stronger impression on the boy through the medium of his sight, that he believes it more confidently. I say that this ought not to be the case. If he does not believe the statement of his teacher—probably a clergyman of mature knowledge, recognised ability, and blameless character—his suspicion is irrational and manifests a want of the power of appreciating evidence, a want fatal to his success in that branch of science he is supposed to be cultivating.'

I take a singular pleasure in this extract. In times of depression it serves as a tonic and drives one to the conclusion that, after all, our progress, however slow, is real, although I have an impression that the Todhunter school is not entirely extinct.

So far, the only result of my inquiries had been the discovery, if discovery it was, that dissatisfaction with our present system was the prevailing sentiment. I decided, therefore, to take the somewhat bold step of endeavouring to ascertain the attitude of those who have most to do with the administration thereof. I ventured to send to all the Directors of Education in England and Wales a series of questions, the answers to which I hoped might throw light on the matter. In order to elicit, if possible, free expression of opinion I stated that their replies would in general be used only for statistical purposes, and in no case would indication be given of the Authority with which the writer was concerned.

I take this opportunity of most sincerely thanking the many Directors who have been so good as to assist me in this inquiry. No fewer than 121 of these gentlemen have undertaken the task of returning replies, and when I reflect upon the extent to which their energies are employed in compiling returns for their various Authorities and for the Board of Education I realise my temerity in thus adding to their labours.

In analysing the replies it has been necessary to divide them into the

[1] It appears that our average expenditure per child per working week (including interest on buildings, &c.) is about 1s. 8*d*. Perhaps we are getting in return as much as we deserve at the price.

following classes, viz.: (1) Counties, (2) county-boroughs, and (3) boroughs and urban districts, as the conditions in these areas, under the Act of 1902, differ considerably.

We must remember that as the Directors of Education have to work the machinery, they are perhaps in a better position than any others to form a judgment as to excellences and defects. True, they look on the matter through official spectacles, which are always more or less tinted, and they may, like many owners of motor-cars, have a tendency to hide imperfections.

In Class 1 (counties) I received replies from thirty-six Directors; in Class 2 (county boroughs) from forty; and in Class 3 (boroughs and urban districts) from forty-five.

The Authorities concerned are fairly representative of all portions of England and Wales, and both of rural and urban districts. In order to render comparisons possible, I express the nature of the replies in percentages of the whole of the class.[2] I believe, however, that the effect of reading out, in circumstances of this kind, a large number of tables containing numerical data would be to occupy a considerable portion of your time, and yet leave but little definite impression. I have, therefore, given these tables as an Appendix to this Address, and will now only trouble you with a reference to the results and some examples of the interesting remarks included in the replies.

My first question was:—

Question I.

'Do you consider that the centralisation of authority in the hands of County Councils has caused any decay of interest in education in your district?'

References to Table 1 will show that while in large areas the effect of the Act has been to stimulate interest in educational matters, in small boroughs and urban districts the reverse has been the case. It is difficult, however, to classify strictly many of the replies, as will be seen from the following examples:—

From the Counties:—

1. 'Some decay in local administrative work; local Managers like dealing with local finance and controlling employees; amongst those most competent to deal with matters of education there has been a considerable increase in interest.'
2. 'Less local interest; Managers do not care to visit and see children being taught what they themselves never learnt and do not understand—*e.g.*, such subjects as light woodwork and clay modelling, and even geography as taught on modern methods.'
3. 'On the whole a stimulating of interest, but in a few places where active School Boards existed the feeling of resentment against loss of power is not yet exhausted.'
4. 'Such interest in Secondary Education as now exists is directly the result of the Act.'
5. 'The interest of the past could often be translated *patronage*.'
6. 'The surest way of creating interest in education is to provide the schools of the country with the best teaching talent; legislation and administration *per se* have very little to do with it.'

County Boroughs:—

1. 'The members of the old School Boards were in constant touch with the schools; the members of the Education Committees who are Councillors have too many other public interests.'
2. 'So far as I know, the centralisation of authority in the hands of County Councils does cause a decay of interest in the local districts.'
3. 'Yes, I think it has, to some extent. The cost of education is now brought more prominently before the ratepayers, and education, rightly or wrongly, gets the blame for any increase in the rates.'
4. 'No. The centralisation in reference to Bodies of School Managers has been accompanied by decentralisation in reference to the work of the Board of Education, and local activities have been stimulated.'

[2] For Tables see Appendix.

My fourth question was :—

QUESTION IV.

'Have your Local Committees, or Bodies of School Managers, the right of appointing (*a*) Head Teachers, (*b*) Assistant Teachers?'

I find that, as regards Head Teachers, more than one-half of the Counties, one-third of the Boroughs, but only a small proportion of the County Boroughs, have delegated all powers; the right of appointing Assistant Teachers being delegated to a slightly greater extent.[3]

Remarks.

1. In one case, where the answer is in the affirmative, it is added: 'The exercise of these powers is not wholly satisfactory.'

2. Where the answer is in the negative: 'Managers used to appoint Head Teachers, but this power has, with very great advantage, been taken back by the Education Committee.'

3. 'At one time Assistants were appointed by local Managers, but it was found that elections were determined too much by local uneducational considerations.'

The general result of the replies indicates that the power of appointment is unsatisfactorily exercised by local Bodies of Managers.

QUESTION V.

'Has your Authority established a College for the training of Elementary Teachers, under its own management, or in conjunction with others?'

I find that as large a proportion as one-seventh of the Authorities (Counties and County Boroughs) whose Directors have returned replies have established Training Colleges. It does not appear, therefore, as if the present dearth of teachers was due to lack of training facilities.

QUESTION VI.

I was anxious to ascertain if the effect of such local Training Colleges was to restrict the freedom of choice of Teachers, and the sixth question was as follows :—

'Is the general effect of the present system to restrict the freedom of choice of Teachers to those from your own locality?'

In about half the Counties the answer is in the affirmative, and in the County Boroughs about four-fifths.

Remarks.

Counties :—

1. 'Yes, unfortunately we are arriving at the state that only local Teachers are employed in local schools—a deplorable condition of things.'

2. 'Yes, an outsider, however good, has very little chance.'

3. 'No, except in Group Schools.'

4. 'No, Assistants are so scarce that an applicant from Timbuctoo would have a good chance of appointment.'

County Boroughs :—

1. 'Our Teachers are home-grown.'

2. 'The tendency in this town has for all time been to provide vacancies for students leaving College who are natives of the town.'

3. 'Yes, in my opinion to the detriment of the teaching given in the schools.'

4. 'Yes, the evil is growing.'

It would appear that, on the whole, the opinion of Directors is that the effect of the establishment of local Training Colleges has been to encourage the evil of what I may term 'inbreeding.'

QUESTION VII.

'Do you consider the curricula of (*a*) Primary, (*b*) Secondary Schools under your Authority as overcrowded? If so, can you indicate the directions in which you consider there could be a reduction?'

[3] As regards Non-Provided Schools, in all cases (by the Act) the power of appointing Head Teachers is in the hands of the Managers.

(a) Primary Schools.
Remarks.

1. 'Yes, the remedy is a longer school life.'
2. 'Yes; it is folly to occupy a whole class for several hours, for example, in making a clay model illustrating the story of Alfred and the cakes.'
3. 'Yes, many children are simply wasting their last six months of school life waiting to be legally exempt from school before taking up manual work.'
4. 'Yes, the remedy not in the reduction of curricula, but in the extension of the child's school life.'
5. 'Yes, teachers fail to look on education as *one* thing, and put the various phases of it in watertight compartments; this is the tyranny of the time-table; one would like to say: Teach what you like, when you like, and how you like.'
6. 'Yes, due to the habit of treating each subject, even preliminary subjects, as though it were absolutely distinct from others.'
7. 'No, but the mistake, I think, lies in expecting each child to take the same quantity of every subject, in other words to develop equally all round. The "broad general education" ideal is responsible for much over-pressure.'
8. 'No; I fear many teachers do not take advantage of the Board of Education regulations, because they do not wish to run against the wishes of the local H.M.I.'
9. 'No, but simplification wanted.'

Rather more than half of the Authorities consulted considered that the curricula of the Elementary Schools are overcrowded, and rather more than a third are of the same opinion as regards the curricula of the Secondary Schools.

(b) Secondary Schools.
Remarks.

1. 'Yes, undoubtedly a tendency to attempt too much and to accomplish too little.'
2. 'Yes, a tendency to widen knowledge at the expense of depth.'
3. 'Yes, owing to an undue pressure on the part of the Inspectors.'
4. 'What is wanted is a sense of proportion.'
5. 'No, if Inspectors do not force particular subjects.'

QUESTION VIII.

'Are you in favour of an increase in the number of vocational schools? Or do you consider that the effect of such increase would be detrimental to the standard of general education throughout the country?'

One-third of the County Directors consulted, and almost half of those of the County Boroughs and Boroughs, answer in the affirmative, whereas rather over one-fifth state their inability to arrive at a conclusion. A number of those who answer in the affirmative qualify their replies by stating: 'For children over fourteen,' or 'General education must be first considered,' 'Provided general education is continued.'

As indicating the different views, the following are typical examples:—

1. 'Yes, in the case of Agriculture.'
2. 'No, not in a rural county.'
3. 'Yes, for children who have passed Standard VI. I think the standard in Secondary Schools would then be higher, as it would keep away from them those children who would not stay for the whole course.'
4. 'Yes. Every boy is born with some aptitude, and education can only proceed as it makes this aptitude central.'
5. 'Strongly of opinion that a child's natural delight in manual skill could be made the means of his training for citizenship, but I object to the schools being used to train the child for a particular trade.'
6. 'Any increase which would bring the British system closer to the American one as regards vocational education would be detrimental.'
7. 'I think them a mistake, as very few boys have any fixed idea of what they will do after leaving school.'
8. 'The result might be lamentable; it might end in everybody being what his father was.'
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A. is in advance of B.; at fifteen they are equal; at sixteen B. is ahead. I am sure of this.'

As a whole the weight of opinion is strongly against any increase in vocational schools for children who have not completed their primary education.

Question IX.

'What is the average size of the classes in your Primary Schools?'

I find that the average size of the classes in the Counties is thirty-four, and in the Boroughs forty-two, and they vary from over sixty-three down to ten. The smaller average in the Counties is evidently due to the large proportion of rural schools.

Remarks.

1. 'I find that from whatever side one approaches reform one is brought up against this nightmare of large classes.'
2. 'Classes are smaller in the Non-Provided Schools.'

Question X.

My next question concerned the Counties only. I was anxious to ascertain the effect of the Clause of the Act which places on the locality the task of finding the greater portion of the money for additional buildings, viz. :—

'Do you consider Par. 18, 1 (*a*), (*c*), (*d*) of the 1902 Act to work harshly or to the disadvantage of educational progress?'

It appears that some 40 per cent. of the Directors are of opinion that the effect of the Clause is unsatisfactory. It must be remembered that it is not probable that the officials of County Councils would regard this matter from an impartial point of view, for, no doubt, the existing conditions lighten the burden of the County rates. It is somewhat surprising that in such circumstances the percentage of those answering in the affirmative is so large.

Remarks.

1. 'Makes the Education Rate very unequal in the County and tends to hinder the provision of new buildings.'
2. 'I think it would be better to have the total capital charge made a County one.'
3. 'It must be admitted that the charge on the locality of three-fourths of the capital expenditure often causes serious local opposition.'
4. 'All the charges for education within the area should fall on the County rate; there is no other logical and defensible plan.'
5. 'There is too much tendency to spend on bricks and mortar; the local opposition, therefore, is not wholly bad.'
6. 'Educational benefits cannot be restricted within the limits of certain parishes.'
7. 'The result is strong local opposition to the provision of desirable local accommodation.'
8. 'Thoroughly bad in theory and works very harshly in practice.'
9. 'At first sight seems detrimental to progress; but real progress can only be made by carrying the general public with us in our work, and to go too fast only implies a set-back in the near future.'

Question XI.

'Has your Council delegated to your Education Committee all the powers permitted by the Act? If not, are you in favour of such delegation?'

I find that while over 90 per cent. of the County Authorities have delegated all powers, less than one-half of the County Boroughs and three-fifths of the Boroughs and Urban Districts have adopted the same course. An overwhelming majority (85 per cent.) of the Directors of all classes are in favour of full delegation.

Remarks.

1. 'Yes, thank goodness.'
2. 'Yes; we should be saved infinite trouble. Some Town Councillors have little sympathy with education.'

3. 'Would prefer total delegation.'

4. 'Most Education Committees are far more progressive than the County Councils appointing them.'

5. 'Strongly in favour of delegation; it would do away with a great deal of delay in administration.'

6. 'An educational point of view of matters would be more frequently considered.'

7. 'Before we had it the Education Committee was, in fact, a plaything of the Council.'

8. 'Such delegation would lead probably to friction in practice.'

9. 'Delegation of such powers is better in all respects for education.'

QUESTION XII.

'Please add any special criticisms of, or suggestions for, improvements in the Act.'

It was very evident that most of my correspondents were anxious to avoid an expression of their views in this matter. The nature of many of the replies may be indicated by that of one of the Directors—namely: 'No, thank you.' On the other hand, several have been so good as to write me short treatises on the subject, containing very valuable expressions of opinion. It is difficult, however, to quote from many of these without betraying the condition on which I invited confidence—namely, that I would give no indication as to the localities concerned. On one matter all who have expressed their opinions are in accord—viz.: 'The greatest difficulty of the Act is the dual control for Non-Provided Schools, more especially with regard to staffing.'

It is stated that 'the transfer and promotion of teachers is almost impossible under the present system.' I feel, however, that the less I touch on this aspect of the matter the better for the peace of mind of this Section. Again, all Directors urge the necessity of relieving the increasing burden of the rates. One states that the proportion of Treasury Grants has dropped from 66 per cent. in 1906 to 48 per cent. in the past year, while the local rate has been nearly trebled. Again: 'Some means should be obtained to enable Authorities with large number of rural schools to provide adequate education without increasing the overwhelming burden now imposed upon them.'

The following are typical examples of the replies received:—

1. 'The greatest difficulty of the Act is the dual control over Non-Provided Schools, more especially with regard to staffing.'

2. 'The whole of the Grant System should be overhauled and put on an entirely new basis. The Authority should be aided, not on the basis of each school, but on the basis of its general efficiency throughout the area.'

3. 'Attendance should not be the only basis on which grants are paid.'

4 'The L.E A. should have statutory rights to consult H.M.I. and to publish his opinions.'

5. 'The exclusion of children under the order of the School Medical Officer should not diminish the grants from taxes.'

6. 'After-care and choice of employment to be statutory duties of L.E.A., and money to be specially allocated.'

7. 'The relative duties of the Board of Education and the L.E.A. in regard to the training of teachers should be clearly defined.'

8. 'The method of dealing with endowments whereby money left for education is now used to relieve local rates should be radically altered.'

9. 'There should be no limit to the Higher Education Rate.'

10. 'The choice of all teachers should be left to the L.E.A.'

11. 'The L.E.A. should have more power and liberty.'

12. 'At present they (L.E.A.) are automatic machines, turning out identical articles till the veneer goes off. Best of all, leave us alone for a few years.'

13. 'The present statutory distinction between Elementary and Higher Education, which hinders efficiency, should be done away with, and all Authorities should be for education generally.'

14. 'Districts, not counties, nor boroughs, should be the educational area.'

15. 'The admission age should be made higher.'

16. 'I doubt if any other civilised country enforces admission at the age of five.'

17. 'The qualification of the Inspecting Staff and of the chief officials of the L.E.A. should be defined by statute.'

18. 'The abolition of autonomous areas. County Authorities would then be masters in their own house, and would be able to co-ordinate different grades of education. Some of these are parochial in the extreme.'

19. 'The provision of share of cost of erection and enlargement of schools should be by the Imperial Exchequer.'

20. 'Small authorities should be grouped, and the number of L.E.A.s would then be reduced; the level of both elected and paid administrators would then be higher.'

21. The necessity for smaller classes is insisted upon by nearly every writer.

22. The last reply which I shall quote is an exceptional one: 'Educationally the Act is a success.'

I may sum up as follows the impression left on my mind by the study of all the replies, of which I have given only a few examples.

1. The Act appears to give greater satisfaction in the Counties than in the County Boroughs and Boroughs and Urban Districts, although even in the Counties the position of the smaller rural schools is a cause of dissatisfaction.

2. That in the Boroughs there is, on the whole, a preponderance of opinion in favour either of an Authority elected *ad hoc*, or a more liberal exercise of the power of co-option.

3. That there is a preponderance of opinion that the appointments of the school teachers should in all cases rest in the hands of the L.E.A.

4. That there is a tendency under the present system, except in centres of large population, to restrict the choice of teachers to those who have received their education locally, and that the effect of such restriction is detrimental.

5. That greater freedom in educational matters is advisable. The effect of the present system is to produce a dull uniformity, although it is doubtful whether the Head Teachers themselves or the Board of Education are most to blame.

6. That an increase in the number of vocational schools is not desirable, unless great care is taken that only those scholars are admitted who have received a sound general education.

7. That one of the greatest hindrances to progress is the large size of the classes.

8. That there should be greater delegation of powers to the Education Committees, and that the L.E.A. should have complete control over all forms of education within its own area.

9. That a Redistribution Bill in the matter of areas is desirable, especially in the relation of urban areas to the rural districts connected with them.

10. That the dearth of fully qualified teachers cannot be remedied until the profession is made sufficiently attractive by increased emoluments and more rapid promotion. Mere increase in the number of Training Colleges is no remedy.

11. And, lastly, there is a consensus of opinion that a greater proportion of the cost of education should be borne by the Treasury, and that the danger to education arising from the rapid rate of increase in the Education Rate is a very real one. If education in this country is to be successful it must be made popular. This is impossible when every step in advance means an addition to the local burdens.

I am afraid that the tenor of this correspondence does little to modify the pessimistic views to which I have previously called attention. Regarded in bulk it conveys the idea that the writers are endeavouring to make the best of a bad case, although, as shown by the last reply quoted (*supra*), the race of Mark Tapleys does not appear to be entirely extinct.

I wish it had been possible to obtain the confidential opinions of H.M.I.s, but I, at all events, am not one who would dare to question the gods, the distinguishing characteristic of those admirable officials being a cold infallibility which renders approach inadvisable. It must be remembered, however, that

veiled hints of the need of drastic reforms have emanated from the highest quarters, and one of the most hopeful signs of the situation is that such information as has been vouchsafed to us appears to indicate that those who are moving in the matter actually acknowledge that there is an educational as well as a sectarian and a political aspect of the question. Nevertheless, so far as I am personally concerned I still find my chief consolation in the quotation from Todhunter which I have already inflicted upon you.

I am now going to take a bold step—namely, to express my own opinion on this matter of Primary Education. I consider that we are proceeding in the wrong order, in that we give greater prominence to the acquisition of knowledge than to the development of character.

There is truth in Emerson's dictum that 'the best education is that which remains when everything learnt at school is forgotten.' We appear to think that the learning of 'the three R's' *is* education. We must remember that in imparting these we are only supplying the child with the *means* of education, and that even when he has acquired them the mere addition of further knowledge is again not education. If we impart the *desire* for knowledge and train the necessary mental appetite, the knowledge which will come by the bucketful in after life will be absorbed and utilised.

It is, I know, easy to talk platitudes of this kind. We have, in justice to the teacher, to remember that character depends on home life, as well as on school life; but, nevertheless, if we could educate public opinion on this matter progress might be possible. We want to introduce the spirit of our much-abused public schools into all schools, namely, a sense of responsibility—and, as a necessary sequence, a sense of discipline—a standard of truthfulness and consideration. In this connection I have been greatly impressed by a report issued by the Warwickshire County Council on the effect of the establishment of the Prefect System in the Elementary Schools of that county, and I wish it was possible to place this Report in the hands of every teacher in the country. It is stated in the introduction that 'the fundamental idea of the Prefect System is the formation and development of character and the utilising for this purpose of the efforts and activities of our pupils themselves.'

The pamphlet contains a description of the system as established, and the different methods adopted in the schools of the county in carrying it into effect.

A summary of the Head Teachers' Remarks, compiled by the Director of Education, is given as an Appendix, and I cannot resist the temptation to quote largely from his Report:—

'In the autumn of 1911 a Conference of Head Teachers was held on Prefect Systems in Elementary Schools. It was then decided that all the Head Teachers present should try the system for a year, each one on his or her own lines, and then report as to its working.

'Nearly all have now made reports, one only having failed without good cause. Reports have come in from six large or middling boys' schools, three large girls' schools, two large mixed schools, eleven middling and small schools, mostly in villages, and one infants' school—twenty-three in all, embracing schools of practically every type.

'The record, with one exception, is a story of success, in most cases of extraordinary success, so much so as to put the possibility and value of the system beyond a doubt. Whether in developing the prefect's own character, or in creating a sense of school honour among the other children, or in smoothing the whole working of the school, the result is equally striking. And the more ambitious the scheme of a school, the more it approximates to the Public School tradition, the bigger the faith in boy and girl nature, the greater has been the success. The few evidences of comparative disappointment come from schools where the system has been tried haltingly and with distrust. Where there has been courageous faith in the children they have risen to it to a degree that must surprise even those who were readiest to believe in school self-government. Nor is the success confined to large schools or boys' schools. Boys' and girls' and mixed schools, town schools and village schools, all have the same tale to tell. A supply teacher who has served in seven schools since the Conference has found

that "from all classes of children, town and country, a ready response is made to an appeal for added responsibility and trust on their part." . . . .

'The prefect, being in authority himself, comes to see the necessity and value of discipline. He is as keen as is his Head for the school's honour; he worries the unpunctual, he takes charge of the playground. He is proud at being asked and able to help in matters of school routine, most of all when the teacher is called out of the class-room and he is himself responsible for order. And woe then to the disorderly or slack! . . . .

'In its way one of the most remarkable applications of the system is its appearance in a miniature form in an infants' school. Children of six and seven, happy in the possession of the monitor's bow of ribbon, take care of the younger children and remove dust which has escaped the caretaker's eye. . . .

'It is a moot point whether a written constitution helps or not. Some teachers deprecate rules, as limiting a prefect's sense of responsibility and his freedom to follow out his own ideas. That rules, however, meet some want seems to be proved by the fact that at a school where the Head Master had purposely made none the boys themselves drew up their code, and, the Head Master adds: "I could not have got out any better rules."'

The origin of the movement whose results are thus described is due to the man whom I regard as the greatest educator of our time—namely, Sir Robert Baden-Powell. I believe that the Boy Scout movement is rendering greater service than our complicated State machinery in preparing those who are brought within its influence for the struggles of life. It is a matter for regret that so small a fraction of the children in our schools is able to share its benefits. I only wish it were possible for our political system to admit the appointment of Baden-Powell as Minister of Education, with plenary powers, for the next ten years!

He states that when visiting a great Agricultural School in Australia he asked the Principal to inform him briefly what was the general trend of his training. The reply was: 'Character first; then Agriculture.'

If this, suitably modified, could be adopted as the motto for all our schools the present attitude of the man in the street towards education would soon undergo modification.

There is truth in Dr. Moxon's statement that 'A man has to be better than his knowledge, or he cannot make use of it,' and our efforts should be mainly directed to making the character and the intelligence of the child so much better than his knowledge that increase in knowledge will follow as a matter of course. Let us devise some kind of universal Junior Scout system which may so brighten the intelligence that the boy will *want to know*. Let him also discover that the paths to knowledge are Reading, Writing, and Arithmetic; he will then gladly follow his guides and gather more by the way than when he is pushed along those paths in a perambulator.

So long as we attach greater importance to the results of examination than to the judgment of the teacher our system stands self-condemned, for it places knowledge above character.

It is natural that the discontented amongst us should try to cast the blame on those in authority, and I confess that at times I feel as if I could join the militant section and relieve my feelings by throwing stones through the windows of the Board of Education; but in recent years I have been privileged to pass to the other side of those windows, and I have, to some extent, been led to realise how able and how devoted are the men to whom the guidance of our educational system is entrusted. All who are brought in contact with them must acknowledge their earnestness and their zeal in the cause in which they are enlisted, and it is remarkable how, in the discussion of educational questions, they can, in moments of partial *abandon*, cease to be strictly official and become almost human. It is evident, however, that the aim of such men must ever be the smooth working of the machine as a whole. The comforting words 'co-ordination,' 'uniformity,' 'efficiency,' are ever in their minds. A system planned on one great design and perfected in all its details is the ideal for which they are bound, consciously or unconsciously, to strive. The pity of it is that the more successful their efforts, the worse it is for education in this country.

Evolutionary progress is only possible where variety exists, and variety

is necessarily abhorrent to the official mind. Freedom for Local Authorities to adopt their own methods, to experiment—and often to fail—is the system, if system it can be called, by which alone advance is possible. The curse of uniformity, perhaps the greatest curse of all, is a necessary consequence of over-centralised control.

I have trespassed so greatly upon your forbearance in discussing matters connected with Primary Education that I must give but brief expression to any views concerning the Secondary and Higher branches.

As I have previously indicated, State aid should be restricted to those who are able to profit thereby. The 25 per cent. free-place regulation has, it is generally admitted, brought into the Secondary Schools many really able students. On the other hand, there is no doubt that a certain proportion thereof would be more profitably employed in serving their apprenticeship in the business in which they are to earn their bread-and-butter. It is, of course, understood that those whose parents can afford to pay for the further education of their children and who are ready to do so are not here referred to, but, careful selection assured, generous assistance to those in need of help suggests itself as the best policy.

Another subject for consideration is the disproportion between the assistance given by the State to the training of Primary and of Secondary Teachers. I understand that to the latter object, so far as England and Wales are concerned, the not impressive sum of 5,000*l.* is delegated. After making due allowance for the difference in numbers under the respective headings, it is difficult to understand how it is necessary to expend a sum approaching 700,000*l.*[1] on the training of Primary Teachers, and only 1/140th of that amount on training those who are to guide our most able students in the pursuit of knowledge.

Had time permitted I should have liked to dwell on the evil effects of what I may term our conspiracy of silence regarding sexual instruction. If the proverbial visitor from Mars was engaged in a tour of inspection in our country, I think nothing would strike him as more extraordinary than that a subject which so closely concerns the progress of the race and the welfare of the individual should be entirely ignored in our system of education. By our action (or rather want of action) we tacitly admit that knowledge is harmful, and that we deliberately prefer such knowledge, which must necessarily be attained in one way or another, to arrive by subterranean channels and by agencies which will present facts of vital importance in their worst possible aspect.

We cannot be said to be really educating our children so long as we withhold from them all guidance in one of the most difficult problems which will be presented to them in later life, and when one reflects on the misery and wreckage consequent on our silence, it is difficult to speak with due moderation. I will therefore content myself with suggesting to those interested in this matter a study of the procedure adopted in the schools of Finland, in which systematic instruction is given by carefully selected teachers; it is stated with the happiest results.

I have referred, when speaking of Primary Education, to the curse of uniformity as one of the greatest evils of our educational system. So far, at all events, our provincial Universities have escaped, although not entirely un-

[1] Note I.—Grants for 1911-12:—

1. Grants from Board of Education:—		
(*a*) Maintenance grants to Training Colleges and Hostels	£470,910	
(*b*) Building grants	93,496	
		£564,406
2. Grants from L.E.A.'s:—		
(*a*) To Training Colleges	21,682	
(*b*) To Hostels	787	
(*c*) Scholarships (not possible to ascertain total)	?	
		22,469
Total		£586,875

Note II.—To the above must be added the grants in aid of bursars and pupil teachers, which amount to £101,802.

scathed, from the cramping effects of departmental control. The situation, however, is not free from danger. It is necessary that these Universities should be State-aided. It is also evident that, if we are to hold our own in competition with other nations, State assistance must be increased. There is danger, therefore, that the blight of uniformity and official control may descend upon them. The danger is not immediate, but it is nevertheless real. To some of us an ominous sign was the transference of the dispensation of the University grants from the Treasury to the Board of Education. It is true that we have evidence that no desire for undue control is manifest at the present time, and it is an encouraging sign that the Minister of Education, in a recent dispute connected with one of our youngest Universities, intimated that he considered it beyond his province to interfere with its proceedings.

In this connection Mr. Austen Chamberlain has given me permission to read the following extract from a letter which I recently received from him :—

'I am in complete agreement with you as to the importance of preserving to the Universities the greatest possible freedom and liberty. For this very reason I was at first strongly opposed to transferring the administration of the Treasury Grants to the Board of Education; but I found that, for one reason and another, a considerable portion of their receipts were already received from the latter Board, and it was represented to me that this involved unnecessary complication and overlapping, and that the Universities were likely to receive more generous consideration if the whole of the Grants were placed in the hands of a single Authority. At the same time I was assured that the Board of Education had no desire to claim a control different in character or extent from that which the Treasury had previously exercised. On receiving these assurances I withdrew my opposition to the transfer and sent word to the Chancellor of the Exchequer that I no longer held him bound by an undertaking which he had given me in the House of Commons that the transfer should not take place.'

Another encouraging sign is the *personnel* of the Advisory Committee which the Board has established to guide it in matters connected with the University Grants. We cannot, however, be certain that such wise views will always prevail, and I have already dwelt on the inevitable tendency of any department of State to influence and control the policy of all Bodies receiving assistance from the Treasury

The freedom of the Universities is one of the highest educational assets of this country, and it is to the advantage of the community as a whole that each University should be left unfettered to develop its energies, promote research and advance learning in the manner best suited to its environment. It is conceivable that it might be better for our Universities to struggle on in comparative poverty rather than yield to the temptation of affluence coupled with State control.

The State is at present devoting some 180,000*l.* to the support of University education in England and Wales. If, in addition, we include such institutions as the National Physical Laboratory and the grant of 4,000*l.* to the Royal Society, we may say that this country is expending about 200,000*l.* per annum on the highest education and the promotion of research, a total but slightly exceeding that devoted to *one* of the Universities of Germany. Comment appears needless.

When we reflect on the magnitude of the results which would inevitably follow an adequate encouragement of research, the irony of the position becomes more evident. It was stated on authority that Pasteur during his lifetime saved for his country the whole cost of the Franco-Prussian War. It is computed that nearly one and three-quarter millions of our population are to-day dependent for their living upon industries connected with the mechanical generation of electricity—a population which may be said, without undue use of imagery, to be living on the brain of Faraday. We possess mathematicians who, granted encouragement, opportunity, and time, could establish the laws of stability of aeroplanes. Suppose we spent some millions in discovering *the* man and enabling him to complete his task; the result might be an addition to our security greater than that of a fleet of super-Dreadnoughts. Unfortunately, there are no votes to be gained by the advocacy of opportunities for research!

Associations such as ours should spare no effort to bring home to the minds of the people the truth of the statement that the prosperity of this kingdom is dependent on its industries, and that those industries are founded on Applied Science.

Some years ago the *Petit Journal* invited its readers to answer the question 'Who were the twenty greatest Frenchmen of the Nineteenth Century?' No less than fifteen million votes were recorded. The resulting list included the names of nine scientific men, and Pasteur led by 100,000 votes over Victor Hugo, who came second, Napoleon securing the fourth place. It is obvious that a poll of such magnitude must have been representative of all classes. I ask you to reflect on the probable result, *mutatis mutandis*, if such a poll was taken in this country. I am afraid we should find the names of football and cricket heroes included, but I doubt if the name of a single man of science would appear amongst the immortals.

It should be our mission to make evident to the working-man his indebtedness to the pioneers of science. Demonstrate to him the close connection between the price of his meat and the use of refrigerating processes founded on the investigations of Joule and Thomson; between the purity of his beer and the labours of Pasteur. Show the collier that his safety is to no small extent due to Humphry Davy; the driver of the electric tramcar that his wages were coined by Faraday. Make the worker in steel realise his obligation to Bessemer and Nasmyth; the telegraphist his indebtedness to Volta and Wheatstone, and the man at the 'wireless' station that his employment is due to Hertz. Tell the soldier that the successful extraction of the bullet he received during the South African War was accomplished by the aid of Röntgen. Convince the sailor that his good 'landfall' was achieved by the help of mathematicians and astronomers; that Tyndall had much to do with the brilliancy of the lights which warn him of danger, and that to Kelvin he owes the perfection of his compass and sounding line. Impress upon all wage-earners the probability that had it not been for the researches of Lister they, or some member of their family, would not be living to enjoy the fruits of their labours. If we can but bring some five per cent. of our voters to believe that their security, their comfort, their health, are the fruits of scientific investigation, then—but not until then—shall we see the attitude of those in authority towards this great question of the encouragement of Research change from indifference to enthusiasm and from opposition to support.

When we have educated the man in the street it is possible that we may succeed in the hardest task of all, that of educating our legislators.

APPENDIX.

Summary of the Replies received from the Directors of Education.

Total number of forms returned: 121.

Question I.

'Do you consider that the centralisation of authority in the hands of County Councils has caused any decay of interest in education in your district?'

Table I.

Authority	Yes	No	No change, or indecisive
	Per cent.	Per cent.	Per cent.
Counties	9	82	9
County Boroughs	27	28	45
Boroughs and Urban Districts	53	26	21

If, disregarding the classification, we take the country as a whole, we get:—

31 per cent. 44 per cent. 25 per cent.

Question II.

'Would you prefer the educational authority to be one elected *ad hoc*, as in the days of the School Board, rather than the system as at present established?'

TABLE II.

Authority	Yes	No	Uncertain or indifferent
	Per cent.	Per cent.	Per cent.
Counties	19	71	10
County Boroughs	55	21	24
Boroughs and Urban Districts	72	23	5
Country as a whole	51	36	13

QUESTION III.

'(*a*) To what extent has co-optation of members of the Education Committee been adopted in your area, *i.e.* what proportion do the co-opted members bear to the whole Committee, and what is the proportion of co-opted women members ?

(*b*) Would you wish to see the principle of co-optation extended or diminished ?'

TABLE III. (*a*)

Percentage of Co-opted Members.

Authority	Average Percentage of Co-opted Members	Highest Percentage	Lowest Percentage	Average Percentage of Women Co-opted	Highest	Lowest
	Per cent.	Per cent.	Per cent.	Per cent.		
Counties	31	44	13	7	11	3
County Boroughs	33	48	6	8	13	3
Boroughs and Urban Districts	30	48	3	9	18	3

TABLE III. (*b*)

Authority	Extended	Diminished	Satisfied with present conditions
	Per cent.	Per cent.	Per cent.
Counties	25	3	72
County Boroughs	21	21	58
Boroughs and Urban Districts	45	12	43

QUESTION IV.

'Have your Local Committees, or Bodies of School Managers, the right of appointing, subject to ratification by the Education Committee, (*a*) Head Teachers; (*b*) Assistant Teachers ?'

TABLE IV. (*a*)

Delegation of Powers.

Head Teachers.

Authority	Delegated	Delegated subject to ratification	Not delegated
	Per cent.	Per cent.	Per cent.
Counties	55	24	21
County Boroughs	14	58	82
Boroughs and Urban Districts	32	6	62

TABLE IV. (*b*)
Assistant Teachers.

Authority	Delegated	Delegated subject to ratification	Not delegated
	Per cent.	Per cent.	Per cent.
Counties	61	27	12
County Boroughs	17	5	78
Boroughs and Urban Districts	36	11	53

QUESTION V.

'Has your Authority established a College for the training of Elementary Teachers, under its own management, or in conjunction with others? If so, has the effect been to restrict the area from which you draw your teachers?'

TABLE V.

Authority	Percentage having established Training Colleges
	Per cent.
Counties	14
County Boroughs	10

QUESTION VI.

'Is the general effect of the present system to restrict the freedom of choice of teachers to those from your own locality?'

TABLE VI.

Authority	Yes	No	Uncertain
	Per cent.	Per cent.	Per cent.
Counties	47	37	16
County Boroughs	80	18	2

QUESTION VII.

'Do you consider the curricula of (*a*) Primary; (*b*) Secondary Schools under your Authority as overcrowded?

'If so, can you indicate the directions in which you consider there could be a reduction?'

TABLE VII.

Authority	Yes	No	Uncertain
(*a*) *Elementary Schools.*			
	Per cent.	Per cent.	Per cent.
Counties	50	46	4
County Boroughs	45	52	3
Boroughs and Urban Districts	62	35	5
(*b*) *Secondary Schools.*[1]			
Counties	42	50	8
County Boroughs	30	65	5

[1] Note.—The number of replies from Boroughs and Urban Districts was insufficient to warrant a table of percentages.

QUESTION VIII.

Are you in favour of an increase in the number of vocational schools? Or do you consider that the effect of such increase would be detrimental to the standard of general education throughout the country?'

TABLE VIII.

Authority	Yes	No	Uncertain
	Per cent.	Per cent.	Per cent.
Counties	33	45	22
County Boroughs	47	26	27
Boroughs and Urban Districts	45	30	25

A considerable proportion of those who say 'Yes' modify their replies by stating, 'For children over fourteen,' or, 'Concurrently with general education.'

QUESTION IX.

'What is the average size of the classes in your Primary Schools?'

TABLE IX.

Authority	Average size of Classes	Highest No.	Lowest No.
Counties	34	60	10
County Boroughs	43	63	10
Boroughs	42	60	10

QUESTION X.

'Do you consider Par. 18, 1 (*a*), (*c*), (*d*), of the 1902 Act to work harshly, or to the disadvantage of educational progress?'

TABLE X.

Authority	Yes	No	Doubtful
	Per cent.	Per cent.	Per cent.
Counties	39	48	13

QUESTION XI.

'Has your Council delegated to your Education Committee the powers under the latter portion of Clause 17 (2) of Part IV. of the Act? If not, would you be in favour of such delegation?'

TABLE XI. (*a*)

Authority	Yes	No	Partly
	Per cent.	Per cent.	Per cent.
Counties	91	3	6
County Boroughs	44	41	15
Boroughs and Urban Districts	58	34	8

TABLE XI. (*b*)

Authority	In favour of delegation
	Per cent.
Counties	89
County Boroughs	93
Boroughs and Urban Districts	74
Mean	85

Joint Discussion with Section H on the Educational Use of Museums.

The following Papers were read :—

1. *The Educational Use of Museums.* *By* JOSEPH A. CLUBB, *D.Sc.*

The public museums of this country are slowly taking their proper position as educational institutions. Just as the departmental museums of universities are the indispensable instruments of scientific teaching and research, so public museums should become the recognised and necessary instruments of popular education. With the ever-widening field of human knowledge, the multiplicity of the collections and departments in our museums is a source rather of bewilderment than of instruction to the average visitor, and perhaps the chief reason why so much of educational value is lost is because there is no comprehensive scheme which will link up and demonstrate intelligently the inter-relation of the various departments both of science and art. In Liverpool we are at present engaged on a scheme which it is hoped will to some extent secure this object. The scheme is described in detail elsewhere,[1] so I propose only to outline it here. A collection is being formed in the main (entrance) hall of the Free Public Museum which is intended to present a connected view of the world in which we live, by suggesting the sequence of its history in a series of cases illustrating (by models, diagrams or specimens) (*a*) the earth in relation with the solar system; (*b*) the surface of the earth (physical and geographical); (*c*) the crust of the earth (geological); (*d*) the life of the earth (biological); (*e*) physical man and (*f*) social man. These cases will therefore form consecutive chapters in an epitome of the world's history, and by placing conspicuously in the respective cases references to the various sections and departments contained in the museum they will also serve as an index to, as well as suggesting the inter relation of, these various sections.

That museums should play an important part in elementary and secondary education will, I think, be recognised, but up to the present little has been done in this country to give it effect. Museum lessons to school children are not unknown, but usually they are not carried out systematically as part of our educational methods, but are intended often rather for amusement than for serious instruction. Various museums have school loan collections, and provide special facilities to encourage visits of school classes under the charge of teachers, and instances are known where some of the more enterprising masters have drawn up courses of lessons in consultation with the curator of the museum. But what has been done is entirely voluntary effort on the part of the teachers, and what is wanted is proper recognition by the Education Authorities that museums are important factors in both elementary and secondary education, together with formal co-operation with museum curators. The faculty which is least trained under our present system of education is that of observation, and yet none is of greater value and none is deserving of more careful cultivation, and the place of all others for such training is a museum. I do not think the formation of 'Children's Museums' is at all necessary. What will educate the ordinary visitor will educate the child, under proper tuition.

The appointment of suitable guides for the purpose of giving demonstrations in museum galleries is full of potentialities for increasing the educational value of museums Museum curators and other members of the staff have done considerable work of this character in the past, but I am of opinion that it will be necessary to appoint guides who can devote the whole of their time to this work.

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2. *The School and the Museum.* *By* A. R. HORWOOD.

The recognition by the State of the principle of facilitating the procedure of elementary school children of merit to the university affords an opportunity for emphasising the unity of all educational institutions.

The school and the university have usually been regarded as the only educational media. But technical schools, agricultural colleges, schools of art are

[1] *The Museums Journal*, vol. xi. 1912.

equally branches of an ideal educational system, integral parts of a whole. And to these and other accessory parts of such a scheme must be added museums and art galleries.

The rise of nature study demands the utilisation of museums for teaching purposes. Already some museums have recognised this, and in many cases for a number of years. But the recognition is not general. Moreover, the interconnection has not, as it ought to have done, come from the schools, which, as a whole, are ignorant of the obvious facilities afforded. State recognition of nature study will improve museums and those who attend and teach in the schools.

The *rapprochement* between museums and schools may be facilitated by the following means: Exhibits may be planned upon an educational basis, as part of a students' section, to suit local needs, illustrating general principles. The existence of such facilities and their application to nature study should be made known. Where there is no other instruction, and there is a demand for it, museum officials may deliver lectures on the subject in connection with the educational exhibits. Lectures to children and demonstrations may also be undertaken by the museum staff. In all cases a definite plan arranged between school and museum authorities should be followed.

The large classes, which hinder effective work in public exhibition rooms, may profitably be allowed to use a room set apart for the purpose of school work. The use of the museum should be regular and on a systematic plan.

Current life—*i.e.*, exhibits of wild flowers, and living animals in aquaria or vivaria—should be encouraged.

This communication draws attention to the unity of all educational establishments, in particular that between schools and museums, and the need for a more general use of the latter by the former.

FRIDAY, SEPTEMBER 12.

Discussion on the Function of the Modern University in the State.

MONDAY, SEPTEMBER 15.

Joint Meeting with Sub-section I (Psychology).

The following Reports and Papers were read :—

1. *Report on the Influence of School-books upon Eyesight.*

See Reports, p. 269.

2. *An Indian National Alphabet.* By Rev. J. KNOWLES.

The necessity for an Indian national alphabet arises from the fact that though India has some two hundred languages and dialects, and, say, fifty different scripts, there is no Indian alphabet, properly so called (except for English). The Indian scripts are really syllabaries, each requiring from 500 to 1,000 complicated types to print. All the characters of a vernacular must be mastered before any reading is possible, and learning to read is as difficult as mastering a system of shorthand.

There are only fifty-three typical elementary sounds in the whole of the Indian languages put together, but there are twenty thousand elaborate symbols used to express them. Many of the characters are extremely trying to the eyesight, and difficult to read, to write, and to print.

These numerous complicated syllabaries are the chief cause of Indian illiteracy, which is so great that 90 per cent. of the males and 99 per cent. of the females are unable to read and write. Out of a total population of over 315,000,000 there are nearly 295,000,000 illiterates. Out of 106,655,443 Hindu females the Census returned 105,847,870 as illiterate, and there were only 137,807 readers among 31,883,812 Mahomedan women and girls.

The simple remedy suggested for this lamentable illiteracy is an Indian national alphabet based upon the Roman letters supplemented by the phonotypes of Sir Isaac Pitman and Dr. A. J. Ellis, with some Romanic letters for special Indian sounds. This alphabet would provide for an accurate transliteration of all Indian languages, or for a practical phonetic writing of the same. In all fifty-three types are suggested, but, on an average, only thirty-seven are required for a vernacular. The letters are easy to read, facile to write, and suitable for printing, and with them an illiterate may be taught to read his mother tongue in ten simple lessons.

It is suggested that Government should appoint a Linguistic Commission to go thoroughly into the whole question of Indian illiteracy and recommend a code of Roman or Romanic letters, which should be allowed *optional* use in the schools and public courts. If this is done, then the great educational, international, economic, and other advantages would soon bring about their general adoption.

In view of the fact that the Indian Government contemplate a wide extension of elementary education the present time seems to present a good opportunity for such an inquiry, and it is suggested that the British Association should take the lead in promoting a memorial to the Secretary of State for India on the subject.

Post-cards giving a complete scheme of Romanic letters for all Indian languages, and illustrating their application to Indian vernaculars (and also to phonetic English as suggested by Sir Isaac Pitman and Dr. Ellis), will be sent to anyone interested on receipt of stamped and addressed envelope. The cards give the printing forms of the letters, the script character, the pronunciation, and the corresponding Sanskrit or Arabic characters. They also show the origin of the present indigenous scripts and give statistical and other information.

Illustrations of Indian scripts and the suggested Romanic letters with specimens of their application to Indian vernaculars and to phonetic English were distributed at the meeting.

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3. *Educational Research.* *By* C. W. Kimmins, *M.A.*, *D.Sc.*

The attitude towards educational research has undergone a remarkable change in recent years. The psychologist is bending his energies more and more towards the solution of important questions of practical education, and the practical teacher is recognising to a far greater extent than previously the great assistance psychology can render in the solution of the problems of the schoolroom. The change of attitude is well exemplified by two books by the same author (Professor Hugo Munsterberg, of Harvard)—'Psychology and Life,' published in 1899, and 'Psychology and the Teacher,' published in 1910.

Whether there is a true science of education or whether such a science is in course of development is not a matter of concern at the moment. What is of more importance is that of recent years scientific methods of investigation have been extensively employed in the solution of educational problems, that universities have regarded such investigations as being worthy of the award of the highest degrees they can offer, and that increased facilities have been given for students of psychology and of the theory and practice of education to take these subjects to a high university standard in their degree courses in Arts and Science (see the recent alterations in the Degree Courses of Study in the University of London).

The so-called 'Downfall of the Theory of Formal Training' is a matter of first-rate importance in its relation not only to methods of teaching, but also to the allocation of time to many subjects in the school curriculum. Dr. Sleight's thesis on 'Memory and Formal Training,' for which he was awarded the

Doctorate in Literature at the University of London, has an all-important bearing on questions relating to the cultivation of memory.

For a considerable time problematical arithmetic has, by common consent, been given a place early in morning school. A careful research recently published, however, gives an account of experiments which show that better results can be obtained by taking this subject at a later hour in the morning, except in the cases of poor children who do work before coming to school. Many such investigations could be quoted to show the great importance of bringing scientific methods of investigation to the questions of school organisation. Such an investigation as that carried out by Mr. Ballard on 'What London children like to draw,' published in the 'Journal of Experimental Pedagogy' for March 1912, is an excellent example of a stimulative and suggestive piece of work.

From a long list of important questions, which need careful scientific investigation, may be mentioned :—

1. The age at which a child should commence to read and write.
2. The best method of teaching reading.
3. The number of hours a child can profitably spend in school at a given age
4. The most suitable length of lessons for children at different ages.
5. The most satisfactory tests of intelligence.
6. The effect of handwork on other branches of instruction and on general mental efficiency.
7. The varying attitude of children towards certain subjects at different ages.
8. The advisability of intensive work at certain stages.
9. The extent to which clever children mature late.
10. The degree to which the curricula of girls' should differ from those of boys' schools.
11. The relative amounts of fatigue experienced in learning certain subjects at different ages.

It would be a great advantage if experimental work in the psychological laboratory could be brought into closer relation with that of the classroom. The results obtained in the classroom should be verified in the laboratory and *vice versâ*. In the classroom the conditions are exceedingly complex and difficult to control, whereas in the laboratory the conditions are simplified as much as possible and may become somewhat artificial. Important results obtained in the laboratory should receive more attention in the school. Similarly, important experiments carried on in the schoolroom should receive the attention of the practical psychologist. It is this forward and backward movement from practice to theory and from theory to practice that will contribute most effectively to genuine advance in education.

A paper read at the Conference of Teachers in London in January 1913, by Mr. Pear of Manchester, on 'Recent Researches on the subject of Attention,' affords remarkable evidence of the practical bearing of laboratory research in psychology on the problems of the schoolroom.

The mass of valuable information which can be obtained from the papers written in connection with the examination of children of various ages in all large centres of population forms an admirable field for work from many points of view, but the statistics must be collected and their significance explained by experienced observers. In America much valuable material has been obtained from the evidence afforded by examination papers of children of different ages.

The number of university students taking educational research for their thesis in higher examinations is increasing rapidly, but it is still in no way commensurate with the importance of this department of knowledge as compared with the amount of research carried on in other departments. The whole matter requires careful organisation, and increased facilities are needed for research. Research Fellowships in education would, in this connection, be of the greatest value to the community and a great stimulus to the science of education.

With advanced work of this kind the difficulties with regard to organisation are not serious, as the students carry on research under university professors in well-equipped institutions, but in more elementary work, for which there

is a large field for workers in many departments, the organisation is more difficult, especially where the correlation of laboratory work and schoolroom work is desirable.

Probably the most effective form of organisation would be the establishment of a board or advisory committee, consisting of professors of education, psychologists and practical teachers, in large centres of population, either under the control of the university or the local education authority, which would be largely responsible for expert guidance and sanction, where necessary, in connection with the conduct of important experiments. In this way teachers wishing to take part in experiments could obtain advice, be warned against the more common errors into which they are likely to fall, and, where they desire it, obtain that necessary training which would qualify them to take part in important investigations in various capacities.

4. *Report on the Mental and Physical Factors involved in Education.*

See Reports, p. 302.

5. *Psychological Analysis and Educational Method in Teaching.* *By* Miss S. Fairhurst.

—See Reports, p. 302.

6. *An Investigation into Spelling at the Fielden Demonstration School.* *By* Miss I. Suddards.

—See Reports, p. 304.

7. *Spelling Reform.* *By* Professor Rippman.

8. *Experiments on the Methods of Teaching Reading.* *By* Dr. C. W. Valentine.

Two classes of students and five classes of Elementary School children, varying in age from six to nine years, were each divided into two sections of approximately equal average intelligence. One section of each class was then taught to read English words written in Greek script, by the Phonic method, the other section of each class being taught to read the same passages by the 'Look-and-Say' (or Word-Whole) method. The same length of time was spent over the lessons given by the respective methods to each class. Subsequently reading tests were given with both seen and unseen words, and the scores of the various sections were compared. On the whole, the Phonic method proved much superior, even with the infant class, and especially in the unseen tests. There was some evidence, however, that for very dull children the 'Look and-Say' method may be preferable.

9. *The Excessive Use of Suggestion in Education.* *By* Mrs. C. M. Meredith.

I. The term suggestion is here used to mean the process of accepting an idea or proposition with conviction, but without adequate logical grounds. The process thus depends (*a*) on the manner of presentation, *e.g.*, the prestige or authority of the person making the suggestion; (*b*) on the state of mind of the recipient, *e.g.*, absence of contrarient ideas, inadequate knowledge. Children consequently are, as a rule, specially suggestible. They accept 'suggested' ideas (1) without opposition; indeed, in the case of indirect suggestion they regard the idea as their own; (2) with a tenacity which they cannot justify; (3) with an emotional tinge which is effective in leading to action.—Ideas due to suggestion contrast with those due to reason.

II. It is at present uncertain how far suggestion is effective in forming children's characters and interests, and at what stage in education suggestion is most influential. In regard to the first point we need to determine how far

a child's interests and convictions are due to native tastes and how far to suggestion. Probably more importance is attached to the former than is justifiable, because the suggested idea, when once accepted, often leads to an habitual interest which appears to subsequent observers as a native taste. In regard to the second point, we need to determine the relative importance of suggestions given in early childhood and those given at adolescence. Educational tradition attaches a possibly exaggerated importance to the former.

III. The more influential we admit suggestion to be, the more cautiously should it be used. (*a*) Its use tends to discourage criticism and reasoning. Much of the adolescent period is wasted in painfully discarding by a critical process the convictions impressed upon us by suggestion during childhood. Unless civilisation is stationary, this is sometimes inevitable. Suggestive methods of education in morals, religion, art, and politics, increase a waste which ought to be minimised. In other cases the critical stage is never reached, and prejudice, or at worst fanaticism, results. (*b*) Its use in teaching and ordinary intercourse to suggest pursuits and arouse interests and to avoid the friction of direct command tends to make the child dependent instead of self-reliant. The more skilful the methods of suggestion, the more is this apt to be the case, because the teacher is himself often unconscious of the extent of his influence. He believes the child to be 'thinking' when in fact he is 'suggesting' each step himself.

IV. The excessive use of suggestion is due to (*a*) bad conditions of teaching and confused criteria of 'good' teaching; (*b*) distrust of reason and the critical faculties. The child cannot in most cases reason adequately, but he should be prepared to reason in the future, instead of being trained to accept unreasoned convictions without criticism.

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10. *Experiments on Practice in Immediate Memory.* *By* J. L. McIntyre.

Preliminary tests were made in several primary and higher grade schools in Scotland, with meaningless syllables as material; their object was to give a standard of unpractised memory, and to determine the influence of different times of exposure and interval, number of repetitions, age, sex, social status, &c. They showed the ordinary gradual increase with age, fluctuations of rise and fall practically alternating for boys and girls, with greater spread of variation for earlier ages, superiority throughout for girls over boys, and for town over country children, the advantage of girls over boys being greater at the lower ages, and greater also for country as compared with town children. Very slight differences were found in results for different rates of exposure (one and a half, two, and three seconds), the quicker reproduction in the first compensating for the longer fixation in the third, but it was found that different methods of memorising were also adopted in the different cases. Visual is throughout more effective than oral presentation, the superiority of the former being greater for older children, and for town as compared with country children. Correlation of the ranking by these tests with the teacher's ranking, in one school, showed extraordinary divergencies in some classes and closeness in others.

The three practice series were carried out in a town school, an oral series (thirty days), a visual (twenty-one days), and a further visual series (sixty days). The improvement was relatively greatest for the oral series (nearly 100 per cent.) and for one as compared with two readings; in the longer visual series, a comparison of the first and last weeks gave an average rise of 50 per cent. Individuals showed well-marked differences of type in the form of the practice curve, and it was found that in most cases the weakest section of the syllable-group was instinctively strengthened as practice continued, becoming in some individuals the strongest by the end of the practice-period. The junior pupils, beginning at a much lower level, made more rapid and greater improvement than the senior pupils, although the difference of age was slight.

An attempt was also made to study the value of such mechanical memory-work as 'formal training'; the results support the view that a considerable amount of the improvement of ability gained by memorising syllables is available for ordinary school-work.

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11. *Analysis and Synthesis in Learning Processes.* *By* Dr. E. O. Lewis.

This paper gave an account of a few initial experiments of a somewhat extensive investigation into the respective rôles of analysis and synthesis in learning processes. Most of these experiments were performed with subjects aged eight to fourteen. In almost all cases the subjects were tested individually, but a few 'mass' experiments were performed to verify some of the chief results.

The first series was designed for the purpose of finding the relative ease and efficiency with which problems are solved or material learnt when subjects proceed (1) from the whole to parts (W method), or (2) from the parts to the whole (P method).

(*a*) Subjects learned to spell strange words which were exposed letter by letter (P method), and another series of words which were apprehended as wholes (W method), the whole word being exposed for the same period as it took to expose a corresponding word letter by letter—usually from ten to fifteen seconds. The data obtained showed conclusively the superiority of the W method, but this superiority was more marked in the complete learning of the matter than in obtaining first impressions. The P method compared more favourably in the learning of Welsh words, *e.g.* 'ynghwydd,' than in learning words constituted of familiar English syllables, *e.g.* 'stimrectwomrud.'

(*b*) In this set of experiments words were exposed in syllables, each consisting of three to six letters (P method), and the results compared with those obtained by learning similar words by the W method. The syllabic presentation was the better both as regards the first impressions and complete learning; but this superiority of the P method was not so marked or consistent as that of the W method in series (*a*) experiments.

(*c*) Drawings of familiar (*e.g.* ship) and unfamiliar (*e.g.* irregular designs) objects were observed and the subjects were asked to draw from memory what they could remember. One set of drawings was observed as wholes, whilst another set was observed in parts. The drawings in the part series were constructed by drawing the object in broad outline first and filling in the details in the succeeding drawings. The reproductions were assessed from the point of view of accuracy and completeness of observation. The results proved the superiority of the W method in a striking manner, especially the reproductions of the familiar objects.

(*d*) Common regular geometrical figures (*e.g.* oblongs, circles) were cut in cardboard into four, five, or six irregular parts. The subjects, mostly adults, were asked to reconstruct the whole by setting the parts together (P method); and to do the converse with another set, by indicating on paper how a given regular figure could be divided into a number of parts which were shown to the subject (W method). The times required to solve the problems were obtained by means of a stop-watch. In all cases the W method proved much the easier procedure.

The contrast between the results of series (*b*) and (*c*) suggested that the superiority of the analytic procedure lies chiefly in mastering organic wholes, whereas the synthetic procedure would prove the better with mechanical wholes. A poem would form an organic whole as compared with a list of nonsense syllables which really only form a mechanical whole. This suggested the following experiment:—

(*e*) A list of associated words, *e.g.* sun, warm, cold, was learnt by the entire method, and a similar list by the sectional method; and likewise with two lists of nonsense syllables. The entire method proved the more economical with both sets of material, but more so with the associated words. The results suggest that to attribute the superiority of the entire method to the saving of unnecessary associations, as is usually done, cannot be regarded as a satisfactory explanation, if indeed it does not overlook the most important factor.

A result of some interest was obtained incidentally from one of the 'mass' experiments. A class of pupils was set the task of making as many sense words as possible in five minutes' time out of the letters of some common word, *e.g.* treasure. The results obtained were correlated with the order of intelligence of the pupils as placed by the class-teacher. The coefficient of correlation was

·19—much lower than was expected. The pupils were given a week's practice in this work, and again tested. The coefficient of correlation proved to be ·54. After still another week's practice the coefficient rose to ·69. Such results prompt us to ask whether tests of intelligence should not give prominence to proficiency in the acquirement of a habit rather than to ability manifested in giving immediate answers to a *questionnaire.*

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12. *The Mental Differences between the Sexes.* By Cyril Burt.

Problems.—Attempts to summarise secondary sex-differences commonly reduce them to terms of a single principle—*e.g.* natural and sexual selection during the evolution of the race (Darwin), abridgment or prolongation of immaturity during the development of the individual (Spencer), environmental influences accumulating through inheritance (Lombroso), environmental influences reimposed but not inherited (Mill), or a fundamental antithesis in physiological constitution (Geddes and Thomson). The implications of such theories suggest the following problems as crucial issues between them: Are the inborn differences between the sexes as large as the acquired? Are the mental differences as large as the physical? Are the differences on the higher levels of mental life as large as those on the lower?

Methods.—These problems require for their solution familiar devices of experimental and statistical procedure.

In collecting data it is necessary to separate inborn mental differences from those that are acquired. In the earlier of the experiments here reported,[1] therefore, the subjects chosen were children of the same age, school, and class, and the tests employed were tasks which depended upon previous knowledge or training to a measurable or negligible extent; in later experiments the groups tested represented various ages from five to twenty-five, and differed in social status and school-training; and the experiments included tests of acquired knowledge and interests.

In calculating results it is necessary to measure the sex-differences in the various tests in the same terms. They are, therefore, expressed in terms of the amount by which the percentage of males exceeding the central measure of the females deviates from 50 per cent. A positive sign indicates that the central measure of the females is surpassed by a majority of the males; a negative sign indicates an analogous superiority on the part of the females.

Results.—It is found that where the two sexes have been taught in different schools, departments, or classes, the differences are much larger than when they have been taught in mixed classes. In the latter case the differences revealed persist throughout the various ages and social classes measured with but little increase or diminution. In the former case they tend to be larger in the case of older subjects and to vary considerably in different social strata.

None of the inborn mental differences are as large as the physical (stature, weight, height, + 47 to + 50 per cent.). The largest inborn differences are found on the lowest levels, in simple processes of sense-perception and movement (*e.g.* skin discrimination, − 43 per cent.; tapping, + 38 per cent.). Instincts and emotions show differences which appear to be somewhat smaller, but are far-reaching in their consequences. On higher levels the differences become progressively still smaller (*e.g.*, memory − 37 per cent., reading − 32 per cent., writing − 20 per cent., addition + 16 per cent., multiplication + 13 per cent.). On the highest levels of all, those concerned with reasoning, these sex-differences are insignificant (*e.g.*, finding opposites − 8 per cent., argument + 7 per cent., syllogisms + 5 per cent.). In general, the higher the process tested and the more complex the capacity involved, the smaller the innate sex-differences tend to become.

Conclusions.—With three of the above principles of explanation (developmental, transmissionist, constitutional), taken singly and alone, these results seem incompatible. The distribution of the differences suggests a composite hypothesis. The larger and more obvious differences seem to be acquired under

[1] A fuller account of the earlier experiments has been published in *The Journal of Experimental Pedagogy*, 1911, 1912.

the influence of the social environment, operating, however, under a bias imparted by congenital differences, and enhanced by peculiarities of physiological development and metabolism. The congenital differences seem adequately explained by natural and social selection, supplemented by alternative inheritance.

TUESDAY, SEPTEMBER 16.

The following Report and Papers were read :—

1. *Report on the Curricula and Educational Organisation of Industrial and Poor Law Schools.*—See Reports, p. 301.

2. *The Registration of Schools. By* Bishop WELLDON, *D.D.*

In regard to the compulsory registration of schools it is necessary to state two leading principles. One is that in education, as in other professions, the age of private adventure is past. The other is that it is desirable to ensure as far as possible the unity of every great profession. From these two principles it follows that all schools, private and public, should stand in some definite relation to the State and to each other. A recent writer in the 'Educational Supplement of *The Times*' has well said that 'no occupation deserves to be called a "profession" until those who pursue it are constituted in some corporate bond, which enables them to speak with the authority of a united voice, not merely as servants of the community, but as honoured and trusted servants, discharging their office, whether public or private, with a fair measure of freedom and independence.' Hence the value of the Registration Council lately established as representative of the whole teaching profession.

But registration implies both inspection of schools and examination of teachers in the schools. Insanitary conditions, noisy, overcrowded classrooms, deficiencies of light, warmth, and space have in time past existed in the greatest and richest schools, like Eton and Harrow, as much as in elementary schools. Nor can it be doubtful, if attention is paid not merely to the few famous public schools but to the multitude and variety of schools all over the country, that every teacher ought to possess, and to be certified as possessing, some definite qualifications for his or her office.

It is well to let in the light upon all schools. If mines and factories cannot safely be left without supervision, neither can schools. Wherever a repugnance to inspection or examination is found, it is probably a sign that something is wrong. Even in schools attached to religious institutions, such as monasteries or convents, a demand for immunity from public control cannot but excite a certain suspicion.

In public schools I have always looked with disfavour and distrust upon masters who did not wish their schools or their forms to be tested by external authority. Confidence between schools and the Board of Education will always be a guarantee of efficiency, or, at least, a safeguard against inefficiency.

But if the registration of schools, with inspection and examination as its concomitants, is to be the rule, why should it not apply to the schools of the Church of England as much as to other schools? I would plead against the educational policy which aims, whether by direct or indirect means, at suppressing denominational schools. But nobody who cares for education as an end in itself, and not as something subordinate to a religious end, can help wishing that denominationalism should not be made a pretext for lowering the standard of material or intellectual excellence in all schools. The Church makes a mistake if she does not seek to set herself in the van of every movement which tends to the elevation of the people. No doubt it is much to be wished that inspectors and examiners, whether they are appointed by the Board of Education or by the Universities, should be wise and moderate in judgment, cautious in procedure, and impartial in their treatment of different schools. But it is only when all schools are related to a central authority that the experience of each school can

be made available, so far as is necessary, for the amelioration of other schools, and that no school will be permitted to sink below the level which enlightened public opinion regards as essential to the welfare of the young, and therefore, as the young will soon be the citizens of the State, to the safety and progress of the nation. The only or the chief danger lying in the control of a central authority is that it may tend to a stereotyped uniformity with little or no provision for experiments: but the educational organisation of a country ought to allow the utmost possible elasticity.

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3. *The Registration of Private Schools.* *By* Sophie Bryant, *D.Sc.*

The first question under consideration is whether private schools should be brought into line with public schools, as part of the national provision for secondary education. This would involve their recognition by the State as efficient for the education of young persons up to the age of sixteen or eighteen. Such recognition could only be given after inspection, and continued subject to inspection, as in Germany. Schools which satisfied the inspectors would be placed on a list of 'Private schools recognised as efficient,' analogous to the Board of Education's existing list of efficient public schools. These two lists might be used by county authorities, to make complete local lists of efficient secondary schools, for their own information and for the use of parents seeking schools. Thus the school supply in each neighbourhood might be better organised and made more useful.

It is a further question whether this process of inspection followed by recognition (or registration), should be compulsory or voluntary on the part of the school. A beginning was made on voluntary lines in connection with the registration of teachers—service in a recognised school being one of the qualifications required—but the attempt ceased when the register was broken up in 1906. It may be revived in some form under the new register. The Colony of Victoria has by this means within the past decade organised all its private schools—its chief secondary school supply—under the State. If a compulsory system is finally established in this country, a preliminary period of voluntary registration has much to be said for it.

Compulsion implies that all educational institutions of a secondary character shall be subject to inspection, and liable to suppression if they are judged to be unfit. The unfit school would no doubt have several warnings before it was condemned. Many struggling schools, conscious of their weakness, would take advice and bring themselves to an end in time. Others would develop reserves of strength and live; others still would save themselves by co-operation and financial partnership. The private schools most likely to survive would be those with high fees and some speciality for which there is a limited but certain demand. The *entrepreneur* who runs cheap schools, chiefly by the labour of others, and is not an educationist, would be faced by the usual alternative when the expenses of a business increase—low profits or high prices with consequent reduction of demand. The schools of the religious orders, on the other hand, would find some way of meeting increased expense, would gain in prestige as in Germany, and derive special advantage from contact with the outer life.

The strong private schools of the more personal type which survive would gain also in prestige, stimulus, and efficiency. Parents would be saved many mistakes and unwise experiments in choice of schools. And children would reap the good result in a continuous education from beginning to end on sound principles and at a high level of efficiency.

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4. *The Registration of Roman Catholic Schools.* *By* Bishop McIntyre.

The State seems to have a right to protect its subjects from being defrauded, as in other matters, so also in the matter of education. It may, therefore, ensure that any educational institution professing to cater for the general public should be really efficient for its professed purpose. The exercise of this right

seems to be demanded in the interest, not only of the commonalty, the parent, and the child, but also of those institutions that are doing efficient work.

Since prevention is better than cure, why should not the State prevent the opening of incompetent institutions? Therefore, why not insist upon registration of schools and teachers?

As Catholics, we have no wish to evade reasonable safeguards taken in this matter by the State. We do not desire to brand ourselves as backward in zeal for education, or as incapable of reaching a common standard of educational efficiency.

On the other side, it may be argued that education is better if left to the action of free competition; that in case of fraud in this matter there is a legal remedy, as in other kinds of fraud; that State control is dangerous as likely either to stiffen into a rigid system which will prevent the expansion of a living education, or to degenerate into that worst kind of tyranny, the tyranny of a bureaucracy.

To strike a balance between these conflicting views, I would concede two points: first, effective supervision over the hygienic conditions of educational institutions, and next, insistence upon the fitness of teachers to teach. Beyond that I am unwilling to go. Education ought to be left as free as possible. Teachers with zeal and education will do their own work best in their own way.

The grounds on which State interference ought to be kept within the specified limits are mainly two: (1) Because private schools represent parental authority, and it belongs to the parent to provide, either by himself or by teachers of his own choice, for the education of his children. The State has no right to interfere, except in case of default through neglect or inability. (2) There is grave danger, of which signs are not wanting, that the State may impose a system of education based on a secular psychology which Catholics cannot accept.

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5. Discussion on the Registration of all Schools.

6. The Need for Experimental Evidence of the Value of Handwork. By P. B. Ballard, *M.A.*

While theories respecting the value of handwork as an educational pursuit are abundant, the extent to which these theories have been demonstrated and verified by experiment is comparatively small. In this paper four of the alleged effects of manual training are considered in the light of a few statistics and experiments, insufficient in themselves to constitute proof, but sufficient to indicate tendencies, and to suggest the kind of testimony required.

1. *Handwork develops Intelligence.*—This is a tremendous claim, and difficult to establish; for psychologists have not arrived at clear and universally accepted views as to the precise nature of intelligence and the extent to which it is cultivable. The clue to the solution of the problem is probably to be found in the doctrine of correlation. On calculating the amount of correlation between handwork and intelligence in two large elementary schools, I found that the coefficient was always positive, and reached as high as ·6 in the lowest classes. It, however, got gradually less for the older children, and sank to ·3 at the top of the school. The interpretation in these results awaits the solution of certain general problems of the correlation of abilities.

2. *A Reasonable Time given to Handwork raises the Level of Attainments in the other Branches of Instruction.*—This is a matter more readily capable of proof, or disproof. No reliable statistical data are, however, available. I have used the mark-sheets of the London County Council Junior County Scholarship Examinations, held in February 1909 and in November 1912, in order to discover the upward or downward tendency in five elementary schools where much handwork has recently been introduced. In School A there was a loss of 4 per cent., in School B a loss of 2½ per cent., in School C a gain of 50 per cent., in School D a gain of 26 per cent., and in School E a gain of 12 per cent. Each of these departments did better at the 1912 examination than the corresponding

departments of the opposite sex. The actual percentages of advantage were 25, 1, 65, 30, and 4, respectively.

A quite unexpected effect of handwork is improvement in English composition.

3. *Certain of the more Academic Branches of Study are best taught practically.*—An experiment was carried out with two classes of children of the same age, all the brighter children being placed in Class A, and the duller in Class B. Class A was taught fractions by means of a piece of apparatus manipulated by the teacher, and Class B by individual work in measuring and cutting paper. When, at the end of six months, the children were tested, Class B did considerably better than Class A.

4. *The Introduction of Handwork into a School tends to reduce the Necessity for Corporal Punishment.*—The punishment books of the five schools referred to above have been examined, and the statistics obtained indicate that when handwork is adopted the number of punishments diminishes—*e.g.*, in School D (a large school) the record is as follows:—

Year . . .	1908	1909	1910	1911	1912	1913 (1st half)
Number of cases	1,406	1,070	746	745	521	280

During 1909 there was a change of headmaster, and at the beginning of 1912 handwork was introduced.

Handwork seems to reconcile the rebellious pupil to his school. It is not unlikely that much of what in the past has been ascribed to a direct transfer of training from manual work to mental work is really due to an indirect influence. The service of the hand reaches the head through the heart.

Of these four alleged effects of handwork I regard the first as possibly true, the second probably true, and the third and fourth certainly true.

7. *Manual Work in Education.* *By* WM. FORTUNE FOWLER.

The ideals which have been so conspicuous a feature of educational reform during recent years are responsible for a series of problems which have yet to be solved in practice:—

How far can the individual child be allowed to educate himself?

To what extent can such heuristic methods be carried in schools where children outnumber teachers by at least forty to one?

In what ways can teachers overcome the difficulty suggested by such outnumbering?

What effect will such methods have upon the child, and how must the curriculum of the school be changed so as to provide suitable exercises?

The author gave an account of an attempt to solve these problems. The children concerned were those of parents belonging to the lower ranks of skilled workers, and may with fairness be regarded as 'average' for the south-east of London.

In the first place a beginning was made with a class of children having an average age of ten and a half to eleven years, and, guided by the needs and difficulties to which these pupils of middle school age confessed, a new experiment with children of eight to nine, nine to ten, and ten to eleven years was conducted.

Both experiments began with handwork as a subject, but the later one quickly developed into a combination of handwork *per se* and handwork as a means of discovery and expression in as many of the school lessons as possible.

The use of plastic materials in the early stages allowed the work to be entirely individual in its character. It was found advisable to introduce gradually a few simple rules, in order to ensure that the modelling was due to control of material. While allowing scope for the imagination by avoiding the rigid limits of always modelling from the object, it was found possible to direct the choice of subject in such a way that certain forms, presenting difficulties capable of classification, were attempted by the whole class.

Ultimately the work was narrowed in scope until the difficulty of the past expression exercises became the basis of a lesson in which the teacher gave con-

siderable guidance. Once taught, the child was encouraged to make this success the nucleus of further experimental work, which later was focussed, as before, upon some failure more or less general throughout the class.

Dealing later with a group of children who had spent some years upon expression work in the infant school, he led more abruptly to those difficulties which fell into an easy classification of forms, capable of being mastered by experiment on the part of the pupil with a little help from the teacher. The interest in the work was greatly stimulated by the confidence which the children gained through successful control of material, and they showed considerable initiative in choosing other work which embodied features thus learnt.

When dealing with more rigid materials the method adopted was somewhat similar, the main difference being that a course of paper-folding was used as the starting-point. The exercises were chosen with a twofold object :—

(a) They were such as were capable of extension by the individual pupils in a great number of ways.

(b) They were models presenting constructional difficulties which would later be met in non-folding materials.

The success of this portion of the work was remarkable from both points of view.

From this point the children were independent of the teacher, except in connection with the modelling of three forms—the cylinder, the pyramid, and the cone. The teaching of these proceeded along the same lines as the early clay work, models of vehicles leading to the cylindrical wheel, those of steeples and tower roofs to the cone and pyramid.

The work of the children abounded in evidence that new problems were solved, somewhat after the manner of Euclid, by reference to previously established methods. Subjects like geography and arithmetic were found to be capable of being taught on similar lines. The curriculum in these cases had to be rearranged here and there. The curtailment of unnecessary and unsuitable matter was found to be far exceeded by the additions which handwork methods made possible.

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8. *Manual Training in the Secondary School.*

By T. S. Usherwood, *B.Sc.*

1. *What Manual Training includes.*—Not mere carpentry, since much of the best modern school work in science and mathematics and practically all art work is involved.

Its value.—Direct and indirect—*i.e.*, as ensuring physical training with parallel mental development, as well as correlating other subjects and offering suggestions for research—no matter whether pursued for purely educational or for ultimately economic reasons.

Its slow development and growth in secondary schools.—Partly due to the overcrowded curriculum and partly due to misconception : the perfunctory consideration it receives, in spite of increasing realisation of its importance.

2. *What is being done.*—Description of a manual training-school; its aim and work.

3. *Criticism.*—The status of manual training and its apparent line of development.

(a) The attitude of teachers of other school subjects; the lack of appreciation of the work, its aims and possibilities; the consequent dissociation of the curriculum.

(b) The prevalence and influence of stereotyped schemes; the tendency to encourage 'tooling' at the expense of construction and investigation.

(c) The lack of teachers capable of extracting all that is educationally most valuable from the work.

4. *Suggestions for improvement and development.*

(a) Fuller and wider recognition, with extended treatment for younger boys—even at the risk of postponing to a later date subjects now regarded as indispensable : the subject to be placed on an equal footing with others, and

regarded as forming an integral part of the curriculum: the necessity for correlation to prevent overlapping and waste of effort.

(b) The importance of elasticity and freedom: attention to be paid to the 'culture' aspect of the training. Recognition of the value of group and research work. Versatility and resourcefulness more important than technique.

(c) Consideration of the types of teachers available: the importance of equality of status and treatment.

WEDNESDAY, SEPTEMBER 17.

The following Report and Paper were read:—

1. *Report on the Distribution and Value of Scholarships, &c., held by University Students.*—See Reports, p. 306.

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2. *The Working of the Education Act,* 1902.
By Sir HERBERT GEORGE FORDHAM.

This paper gave the author's conclusions more particularly derived from his experience of the working of the Act gained as Chairman of the Cambridgeshire County Council and of the County Education Committee. With regard to the administrative machinery set up under Section 19 of the Act, it may be considered a satisfactory experiment in local government, and has probably been most effective under those schemes which maintain the preponderance in Education Committees of members representing County and Borough Councils, with an adequate, but not excessive, proportion of selected educationalists from outside those bodies. As to executive machinery, the author considers that the Clerk of the County Council should have general supervision. He should be the legal and technical adviser, and arrange the Committee's proceedings, minutes, and correspondence; while the head of the Education Office should have a quasi-independence in all matters which are essentially educational in their character, including, of course, everything touching schools and their inspection, and the teaching staff, having the assistance of the County Architect and the County Medical Officers, in addition to his own special staff. The concentration of the supervision of school attendance and kindred matters on a few thoroughly efficient and active officers is important. Under such a system the County of Cambridge has held the first position among the counties of England and Wales in the matter of attendance in elementary schools for three successive years. Second only to the constructive work in respect of the new machinery came the difficult task of examining the position and abilities of the whole teaching staff found in the schools taken over on the 'appointed day,' and the grading of these and all future appointments on settled scales of pay, with complete schemes for increments, advancement, transfers, and special qualifications. Training colleges have yet to be dealt with on some systematic basis, but facilities for training of teachers at all periods of their career in special subjects have been largely provided, and are of great value from various points of view. The author attaches great importance to the Committee itself, or a special sub-committee, directly considering all cases of remuneration, change of status, and of schools and departments which at all depart from the ordinary routine. It is desirable that all reports of H.M. Inspectors should be laid before a sub-committee, if only that close touch may be kept both with the schools and the views of the inspectorate, and that these reports should be controlled by following reports from the County or Borough Inspector. After the study of the teaching staff, that of the fabric and surroundings of each school was a very laborious proceeding, and one which is by no means yet terminated. Lighting, heating, sanitation generally, and the general repair and improvement of the buildings, outbuildings, and playgrounds are always subjects of much concern. A great deal has been achieved in remedying the most serious defect, but there is much to do. Defective heating has been found a very serious evil. The question of small schools and their maintenance in thinly

populated areas, with the alternative of conveying children to school in suitable vehicles, is important. The review of the furniture and apparatus in rural schools has shown that a large proportion is very unsuitable, having regard to modern standards. It is believed that much of the worst of this furniture has now been replaced by modern seating and fittings. School books have been generally considered, and the report of the Committee on this subject is noticed as being of great value. Much progress has been made in introducing in rural schools practical subjects, including particularly woodwork, gardening, and cookery. Medical inspection and its effect on public health, and the standard of health and cleanliness in the home and family are referred to. Important progress has been realised in most districts in this respect, and also in endeavouring to associate parents with a personal interest in school work.

These results are mainly applicable to elementary education. The secondary school system which has been built up under the Act is now fairly complete, and is in itself, and in connection with university training to some extent, a vast constructive result. Scholarships and assistance in various forms now given to children enable the specially talented from all classes to obtain the benefits of the best education of every kind. The advance obtained under the Act and the result of ten years' administration are both very important and generally successful, and justify the labours of the local authorities and of the Board of Education. Among matters remaining for consideration (legislative or departmental) are the co-ordination of university and secondary, and even elementary, education; the institutional training of teachers; the introduction of medical inspection and sanitary supervision in secondary schools, and the structural improvement of all defective elementary schools.

Section M.—AGRICULTURE.

President of the Section—Professor T. B. Wood, M.A.

THURSDAY, SEPTEMBER 11.

The President delivered the following Address:—

I propose to follow the example of my predecessor of last year, in that the remarks I wish to make to-day have to deal with the history of Agriculture. Unlike Mr. Middleton, however, whose survey of the subject went back almost to prehistoric times, I propose to confine myself to the last quarter of a century—a period which covers what I may perhaps be permitted to call the revival of Agricultural Science.

Twenty-five years ago institutions concerned with the teaching of agriculture or the investigation of agricultural problems were few and far between. I do not propose to waste time in giving an exhaustive list, nor would such a list help me in developing the argument I wish to lay before the Section. It will serve my purpose to mention that organised instruction in agriculture and the allied sciences was already at that date being given at the University of Edinburgh and at the Royal Agricultural College, whilst, in addition, one or more old endowments at other Universities provided courses of lectures from time to time on subjects related to rural economy. Agricultural research had been in progress for fifty years at the Rothamsted Experimental Station, where the work of Lawes and Gilbert had settled for all time the fundamental principles of crop production. Investigations of a more practical nature had also been commenced by the leading agricultural societies and by more than one private landowner.

In these few sentences I have endeavoured to give a rough, but for my purpose sufficient, outline of the facilities for the study of Agricultural Science twenty-five years ago, at the time when the County Councils were created. Their creation was followed almost immediately by what can only be called a stroke of luck for agriculture. The Chancellor of the Exchequer found himself with a considerable sum of money at his disposal, and this was voted by Parliament to the newly created County Councils for the provision of technical instruction in agriculture and other industries.

Farmers were at that time struggling with the bad times following the wet seasons and low prices of the 'seventies and 'eighties, and some of the technical instruction grant was devoted to their assistance by the County Councils, who provided technical instruction in agriculture. Thus, for the first time considerable sums provided by the Government were available for the furtherance of agricultural science; and, although at first there was no general plan of working and every county was a law unto itself, the result has been a great increase of facilities for agricultural education and research.

Almost every county has taken some part. The larger and richer counties have founded agricultural institutions of their own. In some cases groups of counties have joined together and federated themselves with established teaching

institutions. For my purpose it suffices to state, without going into detail, that in practically every county, in one way or other, attempts have been made to carry out investigations of problems related to agriculture.

Twenty years after the voting of the technical instruction grant to the County Councils, Parliament has again subsidised agriculture, in the shape of the Development Fund, by means of which large sums of money have been devoted to what may be broadly called Agricultural Science. It seems to me that the advent of this second subsidy is an occasion when this Section may well pause to take stock of the results which have been achieved by the expenditure of the technical education grant. I do not propose to discuss the results achieved in the way of education, although most of the technical instruction grant has been spent in that direction. It will be more to the point in addressing the Agricultural Section to discuss the results obtained by research.

The subject, then, of my Address is the result of the last twenty years of agricultural research, and I propose to discuss both successes and failures, in the hope of arriving at conclusions which may be of use in the future.

Agricultural Science embraces a variety of subjects. I propose to consider first the results which have been obtained by the numerous practical field experiments which have been carried out in almost every county. I suppose that the most striking result of these during the last twenty years is the demonstration that in certain cases phosphates are capable of making a very great increase in the crop of hay, and a still greater increase in the feeding value of pastures. This increase is not yielded in all cases, but the subject has been widely investigated, and the advisory staffs of the colleges are in a position to give inquirers reliable information as to the probability of success in almost any case which may be submitted to them. This is a satisfactory state of things, and the question naturally arises : How has it come about?

On looking through the figures of the numerous reports which have been published on this subject, it appears at once that in many cases the increase in live-weight of sheep fed on plots manured with a suitable dressing of phosphate has been twice as great as the increase in weight of similar animals fed on plots to which phosphate has not been applied. Now about a difference of this magnitude between two plots there can be no mistake. It has been shown by more than one experimenter that two plots treated similarly in every way are as likely as not to differ in production from their mean by five per cent. of their produce, and this may be taken as the probable error of a single plot. Where, as in the case of many of the phosphate experiments, a difference of 100 per cent. is recorded, a difference of twenty times the probable error, the chances amount to a certainty that the difference is not an accidental variation, but a real effect of the different treatment of the two plots. The single-plot method of conducting field trials, which is the one most commonly used, is evidently a satisfactory method of measuring the effects of manures which are capable of producing 100 per cent. increases. It was good enough to demonstrate with certainty the effects of phosphatic manuring on many kinds of grass land, and it is to this fact that we owe one of the most notable achievements of agricultural science in recent years.

Another notable achievement is the discovery that in the case of most of the large-cropping varieties of potatoes the use of seed from certain districts in Scotland or the northern counties of Ireland is profitable. This is another instance of an increase large enough to be measured accurately by the single-plot method. Reports on the subject show that seed brought recently from Scotland or Ireland gives increased yields of from thirty to fifty per cent. over the yields produced by seed grown locally for three or more years.

That the single-plot method fails to give definite results in many cases where it has been used for manurial trials is a matter of common knowledge. Half the reports of such trials consist of explanations of the discrepancies between the results obtained and the results which ought to have been obtained. The moral is obvious. The single-plot method, which suffices to demonstrate results as striking as those given by phosphates on some kinds of pasture land, signally fails when the subject of investigation is concerned with differences of ten per cent. or thereabouts.

Before suggesting a remedy for this state of things it will be well to consider

the allied subject of variety testing, which has been brought into great prominence recently by the introduction of new varieties of many kinds of farm crops. In testing a new variety it is necessary to measure two properties—its quality and its yielding capacity—for money-return per acre is obviously determined by the product of yielding capacity and quality as expressed by market price. I propose here to deal only with the determination of yielding capacity. The determination of quality is not allied to manurial trials.

In attempting to determine yielding capacity there has always been a strong temptation to rely on the measurement of obvious structural characters. For instance, in the case of cereals many farmers like large ears, no doubt with the idea that they are an indication of high yielding capacity. Many very elaborate series of selections have been carried out, on the assumption that large grains, or large ears, or many ears per plant implied high yield.

We may take it as definitely settled that none of these characters is reliable, and that the determination of yielding capacity resolves itself into the measurement of the yield given by a definite area. The actual measurement, therefore, is the same as that made in manurial trials, and is, of course, subject to the same probable error of about five per cent.

It follows, therefore, that it is subject to the same limitations. Variety trials on single plots, and that is the method commonly used, will serve to measure variations in yielding capacity of thirty per cent., or more, but are totally inadequate to distinguish between varieties whose yielding capacities are within ten per cent. of each other.

Numbers of such single-plot trials have been carried out, with the result that many varieties with yielding capacities much below normal have almost disappeared from cultivation, and those commonly grown do not differ greatly from one another—probably not more than ten per cent.

Ten per cent. in yielding capacity, however, in cereals means a return of something like 15*s*. to 20*s*. per acre—a sum which may make the difference between profit and loss; and if progress is to be made in manuring and variety testing some method must be adopted which is capable of measuring accurately differences in yield per unit area of the order of ten per cent.

The only way of decreasing the probable error is to increase the number of plots, and to arrange them so that plots between which direct comparison is necessary are placed side by side, so as to reduce as much as possible variations due to differences in soil. Thus it has been shown that with ten plots in five pairs the probable error on the average can be reduced to about one per cent., in which case a difference of from five to ten per cent. can be measured with considerable certainty.

Such a method involves, of course, a great deal of trouble; but agricultural science has now reached that stage of development at which the obvious facts which can be demonstrated without considerable effort have been demonstrated, and further knowledge can only be acquired by the expenditure of continually increasing effort. In fact, the law of diminishing return holds here, as elsewhere.

It appears, then, that for questions involving measurements of yield per unit area, such, for instance, as manurial or variety trials, further advance is not likely to be made without the expenditure of much more care than has been given to such work in the past. The question naturally arises: Is it worth while? I think the following instance shows that it is:—

Some years ago an extensive series of variety trials was carried out in Norfolk, in which several of the more popular varieties of barley were grown side by side at several stations for several seasons. In all, the trial was repeated eleven times. As a final result it was found that Archer's stiff-straw barley gave ten per cent. greater yield than any other variety included in the trials, and by repetition of the experiment the probable error was reduced to one and a half per cent. The greater yield of ten per cent., being over six times the probable error of the experiment, indicates practical certainty that Archer barley may be relied on to give a larger crop than any of the other varieties with which it was compared. One difficulty still remained. It was almost impossible to obtain anything like a pure strain of Archer barley. Samples of Archer sold for seed commonly contained twenty-five per cent. of other varieties. This difficulty

was removed by Mr. Beaven, who selected, again with enormous trouble, a pure high-yielding strain of Archer barley. Since this strain was introduced into the Eastern Counties the demand for it has always exceeded the supply which could be grown at Cambridge and at the Norfolk Agricultural Station, and it is regarded by farmers generally as a very great success.

The conclusion, therefore, is that a ten per cent. difference is well worth measuring, that it cannot be measured with certainty by the single-plot method, and that it behoves those of us who are concerned with field trials to look to our methods, and to avoid printing figures for single-plot experiments which may very well be misleading. Almost everyone thinks himself competent to criticise the farmer, who is commonly described as too self-satisfied to acquaint himself with new discoveries, and too conservative to try them when they are brought to his notice. Let us examine the real facts of the case. Does the farmer ignore new discoveries? The largely increasing practice of consulting the staffs of the agricultural colleges, which has arisen among farmers during the last few years, conclusively shows that he does not; that he is, in fact, perfectly ready to avail himself of sound advice whenever he can. Is he too conservative to try new discoveries when brought to his notice? The extraordinary demand for seed of the new Archer barley quoted above, and for seed of new varieties generally, the continuous advance in the prices of phosphatic manures, as the result of increased demand by farmers, the trade in Scotch and Irish seed potatoes, all show how ready the farmer is to try new things. The chief danger seems to be that he tries new things simply because they are new, and he may be disappointed if those who are responsible for the new things in question have not taken pains to ascertain with certainty that they are not only new but good. Farmers are nowadays in what may be called a very receptive condition. Witness the avidity with which they paid extravagant prices for single tubers of so-called new, but inadequately tested, varieties of potatoes some years ago, and in a less degree the extraordinary demand for seed of the much-boomed French wheats, and the excitement about nitragin for soil or seed inoculation. Witness, too, the almost universal failure of the new potatoes and French wheats introduced during the boom, and the few cases in which nitragin gave any appreciable result. The farmer who was disappointed with his ten-guinea tuber, his expensive French wheat, or his culture of nitragin cannot but be disillusioned. Once bitten, twice shy. He does not readily take advice again.

Let us, therefore, recognise that the farmers of the country are ready to listen to us, and to try our recommendations, and let that very fact bring home to us a sense of our responsibility. All that is new is not, therefore, necessarily good. Before we recommend a new thing let us take pains to assure ourselves of its goodness. To do so we must find not only that the new thing produces a greater return per acre, but that the increased return is worth more than it costs to produce, and we must also define the area or the type of soil to which this result is applicable. This implies in practice that each field trial should confine itself to the investigation of only one, or, at most, two, definite points, since five pairs of plots will be required to settle each point; that the experimental results should be reviewed in the light of a thorough knowledge of farm book-keeping, and that accurate notes should be taken of the type of the soil, and the area to which it extends, and of the various meteorological factors which make up the local climate. At present we are not in possession of a sufficient knowledge of farm accountancy, but there is hope that this deficiency will be removed by the work of the Institute for Research in Agricultural Economics, which has recently been founded at Oxford by the Board of Agriculture and the Development Commission. The excellent example set by Hall and Russell in their 'Survey of the Soils and Agriculture of the South-Eastern Counties,' an example which is being followed in Cambridge and elsewhere, seems likely to result in the near future in a complete survey of the soils of England which will make a sound scientific basis for delimiting the areas over which the results of manurial or variety trials are applicable.

Reviewing this branch of agricultural science, the outlook is distinctly hopeful. New fertilisers are coming into the market, as, for instance, the various products made from atmospheric nitrogen. New varieties of farm crops are being produced by the Plant-breeding Institute at Cambridge, and elsewhere.

It is to be hoped that the work of the Agricultural Economics Institute at Oxford will throw new light on the interpretation of experimental results from the accountancy standpoint. Finally, the soil surveys on which the colleges have seriously embarked will assist in defining the areas over which such results are applicable. It only remains for those of us who are responsible for the conduct of field trials to increase the accuracy of our results, and the steady accumulation of a mass of systematic and scientific knowledge is assured. It will be the business of the advisory staffs with which the colleges have recently been equipped by the Board of Agriculture and the Development Commission to disseminate this knowledge in practicable form to the farmers of this country.

One more point, and I have finished this section of my Address. I have perhaps inveighed rather strongly against the publication of the results of single-plot trials. I quite recognise that the publication of such results was to a great extent forced upon those experimenters who were financed by annually renewed grants of public money. Nowadays, however, agricultural science is in a stronger position, and I venture to hope that most public authorities which subsidise such work are sufficiently alive to the evils attendant on the publication of inconclusive results to agree to continue their grants for such periods as may suffice for the complete working out of the problem under investigation, and to allow the final conclusions to be published in some properly accredited agricultural journal, where they would be readily and permanently available to all concerned. This would in no wise prevent their subsequent incorporation in bulletins specially written for the use of the practical farmer.

So far I have confined my remarks to subjects of which I presume that every member of the Section has practical experience, subjects which depend on the measurement of the yield per unit area. These subjects, however, although they have received far more general attention than anything else, by no means comprise the whole of agricultural science. Certain scientific workers have confined their efforts to the thorough solution of specific and circumscribed problems. I propose now to ask the Section to direct its attention to some typical results which have been thus achieved during the last twenty years.

The first of these is the development of what I may call soil science. Twenty years ago the bacteriology of nitrification had just been worked out by Warington and by Winogradski. The phenomena of ammoniacal fermentation of organic matter in the soil were also fairly well established. The fixation of atmospheric nitrogen by organisms symbiotic on the Leguminosæ had been definitely demonstrated. Fixation of nitrogen by free-living organisms had been suggested, but was still strenuously denied by most soil investigators. No suggestion had yet been made of the presence in normal soils of any factor which inhibited crop-production. The last twenty years have seen a wonderful advance in soil science. Our knowledge of nitrification and ammoniacal fermentation has been much extended. The part played by the nodule organisms of the Leguminosæ has been well worked out, has seen a newspaper boom, and a subsequent collapse, from which it has not yet recovered. But the greatest advance has been the discovery of the part played by protozoa in the inhibition of fertility.

The suggestion that ordinary soils contained a factor which limited their fertility emanated in the first instance from the American Bureau of Soils. The factor was at first thought to be chemical, and its presence was tentatively attributed to root excretion. Certain organic substances, presumably having this origin, have been isolated from sterile soils, and found to retard plant growth in water culture. It is claimed, too, that the retardation they cause is prevented by the presence of many ordinary manurial salts with which they are supposed to form some kind of combination.

Contributions to the subject have come from several quarters, but whilst the suggested presence of an inhibitory factor has been generally confirmed, its origin as a root-excretion and its prevention by manurial salts has not received general confirmation outside American official circles. The matter has been strikingly cleared up by the work of Russell and Hutchinson at Rothamsted, who observed that the fertility of certain soils which had become sterile was at once restored by partial sterilisation, either by heating to a temperature below 100° C., or by the use of volatile antiseptics such as toluene. This observation

suggested that the factor causing sterility in these cases was biological in nature, that it consisted, in fact, of some kind of organism inimical to the useful fermentation bacteria, and more easily killed than they by heat or antiseptics. After a long series of admirable scientific investigations these workers and their colleagues have shown that soils contain many species of protozoa, which prey upon the soil bacteria, whose numbers they keep within definite limits. Under certain circumstances, such, for instance, as those existing in the soil of sewage farms, and in the artificial soils used for the cultivation of cucumbers, tomatoes, &c., under glass, the protozoa increase so that the bacteria are reduced below the numbers requisite to decompose the organic matter in the soil into substances suitable for absorption by the roots of the crop. Practical trials of heating such soils, or subjecting them to the action of toluene, or other volatile antiseptics, have shown that their lost efficiency can thus be easily restored, and the method is now rapidly spreading among the market gardeners of the Lea Valley.

I have attempted to sketch the chief points of this subject with some detail in order to show that strictly scientific work, quite outside the scope of what some people still regard as 'practical,' may result in discoveries which, apart from their great academic interest, may at once be turned to account by the cultivator. The constant renewal of expensively prepared soil which becomes 'sick' in the course of a year or so is a serious item in the cost of growing cucumbers and tomatoes. It can now be restored to fertility by partial sterilisation at a fraction of the cost of renewal, and considerable sums are thus saved by the Lea Valley growers.

For my second instance of scientific work which has given results of direct value to farmers, I must ask to be allowed to give a short outline of the wheat-breeding investigations of my colleague Professor Biffen. Even as late as fifteen years ago plant-breeding was in the purely empirical haphazard stage. Then came the rediscovery of Mendel's Laws of Heredity, which put in the hands of breeders an entirely new weapon. About the same time the Millers' Association created the Home-grown Wheat Committee, of which Biffen was a member. Through this Committee he was able to define his problem as far as the improvement of English wheat was concerned. There appeared to be two desiderata: (1) The production of a wheat which would crop as well as the best standard home-grown varieties, at the same time yielding strong grain, *i.e.*, grain of good milling and baking quality; and (2) the production of varieties of wheat resistant to yellow rust, a disease which has been computed to decrease the wheat crop of the world by about one-third.

The problem having been defined, samples of wheat were collected from every part of the world and sown on small plots. From the first year's crop single ears were picked out and grown on again. Thus several hundred pure strains were obtained. Many were obviously worthless. A few possessed one or more valuable characteristics: strong grain, freedom from rust, sturdy straw, and so on. These were used as parents for crossing, and from the progeny two new varieties have been grown on, thoroughly tested, and finally put on the market. Both have succeeded, but both have their limitations. Burgoyne's Fife, which came from a cross between strains isolated respectively from Canadian Red Fife and Rough Chaff, was distributed by the Millers' Association after a series of about forty tests, in which it gave an average crop of forty bushels per acre of grain, which milled and baked practically as well as the best imported Canadian wheat It is an early-ripening variety which may even be sown as a spring wheat. It has repeatedly been awarded prizes for the best sample of wheat at shows, but it only succeeds in certain districts. It is widely and successfully grown in Bedfordshire and Dorset, but has not done well in Norfolk. The other variety, Little Joss, succeeds much more generally. In a series of twenty-nine trials scattered between Norfolk and Shropshire, Kent and Scotland, it gave an average of forty-four bushels per acre, as compared with forty bushels given by adjoining plots of Square Head's Master. It originated from a cross between Square Head's Master and a strain isolated from a Russian graded wheat known as Glinka. Its grain is the quality of ordinary English wheat. It tillers exceptionally well in the spring, and is practically rust-proof. Its one drawback is its slow growth during the winter if sown at all late. It has met with its greatest success in the Fen districts, where rust is more than usually virulent.

The importance of this work is not to be measured only by the readiness with which the seed of the new varieties has been tried by farmers and the extent to which it has succeeded. The demonstration of the inheritance of immunity to the disease known as yellow rust, the first really accurate contribution to the inheritance of resistance to any kind of disease, inspires hope that a new method has appeared for the prevention of diseases in general.

Biffen's work too shows the enormous value of co-operation between the investigator and the buyer in defining problems connected with the improvement of agricultural produce. It is open to doubt if a committee of farmers would have been able to define the problems of English wheat production as was done by the Millers' Committee, and in the solution of any problem its exact definition is half the battle. Mackenzie and Marshall in their work on the 'Pigmentation of Bacon Fat' and on the spaying of sows for fattening, have found the great value of consultation with the staffs of several large bacon factories. There seems to be in this a general lesson that before taking up any problem one should get into touch not only with the producers but with the buyers, from whom much useful information can be obtained.

I feel that Biffen's work has borne fruit in still another direction, for which perhaps he is not alone responsible. Twenty years ago Agricultural Botany took a very subsidiary position in such agricultural examinations as then existed. In some of the agricultural teaching institutions there was no botanist, in others the botanist was only a junior assistant. It is largely due to the work of Biffen and the botanists at other agricultural centres that botany is now regarded as perhaps the most important science allied to agriculture.

I must here repeat that I am not attempting to make a complete survey of all the results obtained in the last twenty years. My object is only to pick out some of the typical successes and failures and to endeavour to draw from their consideration useful lessons for the future. So far I have not referred to the work which has been done in the nutrition of animals, and I now propose to conclude with a short discussion of that subject. The work on that subject which has been carried out in Great Britain during the last twenty years has been almost entirely confined to practical feeding trials of various foods or mixtures of foods, trials which have been for the most part inconclusive.

It has been shown recently that if a number of animals in store condition are put on a fattening diet, at the end of a feeding period of twelve to twenty weeks about half of them will show live-weight increases differing by about fourteen per cent. from the average live-weight increase of the whole lot. In other words, the probable error of the live-weight increase of a single fattening ox or sheep is fourteen per cent. of the live-weight increase. This being so, it is obvious that very large numbers of animals must be employed in any feeding experiment which is designed to compare the feeding value of two rations with reasonable accuracy. For instance, to measure a difference of ten per cent. it is necessary to reduce the probable error to three per cent. in order that the ten per cent. difference may have a certainty of thirty to one. To achieve this, twenty-five animals must be fed on each ration. Those conversant with the numerous reports of feeding trials which have been published in the last twenty years will agree that in very few cases have such numbers been used. We must admit then that many of the feeding trials which have been carried out can lay no claim to accuracy. Nevertheless, they have served a very useful purpose. From time to time new articles of food come on the market, and are viewed with suspicion by the farmers. These have been included in feeding trials and found to be safe or otherwise, a piece of most useful information. Thus, for instance, Bombay cotton cake, when first put on the market, was thought to be dangerous on account of its woolly appearance. It was tried, however, by several of the agricultural colleges and found to be quite harmless to cattle. Its composition is practically the same as that of Egyptian cotton cake, and it now makes on the market practically the same price.

Soya-bean cake is another instance of a new food which has been similarly tested, and found to be safe for cattle if used in rather small quantities and mixed with cotton cake. The price is now rapidly rising to that indicated by its analysis. Work of this kind is, and always will be, most useful. Trials with few animals, whilst they cannot measure accurately the feeding value

of a new food, are quite good enough to demonstrate its general properties, and its price will then gradually settle itself as the food gets known.

Turning to the more strictly scientific aspects of animal nutrition, entirely new ideas have arisen during the last twenty years. I propose to discuss these shortly, beginning with the proteins. Twenty years ago the generally accepted view of the rôle of proteins in nutrition was that the proteins ingested were transformed in the stomach and gut into peptones, and absorbed as such without further change. Splitting into crystalline products, such as leucin and tyrosin, was thought only to take place when the supply of ingested protein exceeded the demand, and peptones remained in the gut for some time unabsorbed. It is now generally agreed that ingested protein is normally split into crystalline products which are separately absorbed from the gut, and built up again into the various proteins required by the animal. If the ingested protein does not yield a mixture of crystalline products in the right proportions to build up the proteins required, those crystalline products which are in excess are further changed and excreted. If the mixture contains none of one of the products required by the animal, then life cannot be maintained. This has been actually demonstrated in the case of zein, one of the proteins of maize, which contains no tryptophane. The addition of a trace of tryptophane to a diet, in which zein was the only protein, markedly increased the survival period of mice.

The adoption of this view emphasises the importance of a knowledge of the composition of the proteins, and especially of a quantitative knowledge of their splitting products, and much work is being directed to this subject in Germany, in America, and more recently in Cambridge as a result of the creation there of an Institute for Research in Animal Nutrition by the Board of Agriculture and the Development Commission. This work is expected ultimately to provide a scientific basis for the compounding of rations, the idea being to combine foods whose proteins are, so to speak, complementary to each other, one giving on digestion much of the products of which the other gives little. Meantime, it is desirable that information should be collected as to mixtures of foods which are particularly successful or the reverse.

Here the question arises, for what purpose does the animal require a peculiarly complicated substance like tryptophane? The natural suggestion seems to be that the tryptophane grouping is required for the building up of animal proteins. It has also been suggested that such substances are required for the formation of hormones, the active principles of the internal secretions whose importance in the animal economy has received such ample demonstration in recent years. The importance of even mere traces of various substances in the animal economy is another quite recent conception. Thus it has been shown, both in Cambridge and in America, that young animals fail to grow on a diet of carefully purified casein, starch, fat, and ash, although they will remain alive for long periods. In animals on such a diet, however, normal growth is at once started by the addition of a few drops of milk or meat juice, or a trace of yeast, or other fresh animal or vegetable matter. The amount added is far too small to affect the actual nutritive value of the diet. Its effect can only be due to the presence of a trace of some substance which acts, so to speak, as the hormone of growth. The search for such a substance is now being actively prosecuted. Its discovery will be of the greatest scientific and practical interest.

Evidently new ideas are not lacking amongst those who are engaged in investigating the rôle of the proteins and their splitting products in the animal economy. But of more immediate practical interest is the question of the amount of protein required by animals under various conditions. It is obviously impossible to fix this amount with any great accuracy, since proteins differ so widely in composition, but from many experiments, in which a nitrogen balance between the ingesta and the excreta was made, it appears that oxen remain in nitrogenous equilibrium on a ration containing about one pound of protein per 1,000 pounds live-weight per day. All the British experiments of a more practical nature have been recalculated on a systematic basis by Ingle, and tabulated in the 'Journal of the Highland and Agricultural Society.' From them it appears that increase of protein in the ration, beyond somewhere between one and a half and two pounds per 1,000 pounds live-weight per day

of digestible protein, ceases to have any direct influence on increase in live-weight.

We may fairly conclude, then, that about two pounds of protein per 1,000 pounds live-weight per day is sufficient for a fattening ox. This amount is repeatedly exceeded in most of the districts where beef production is a staple industry, the idea being to produce farmyard manure rich in nitrogen. The economy of this method of augmenting the fertility of the land is very doubtful. The question is one of those for the solution of which a combination of accurate experiment and modern accountancy is required. Protein is the most expensive constituent of an animal's dietary. If the scientific investigator, from a study of the quantitative composition of the proteins of the common farm foods, and the economist, from careful dissection of farm accounts, can fix an authoritative standard for the amounts of protein required per 1,000 pounds live weight per day for various types of animals, a great step will have been made towards making mutton and beef production profitable apart from corn-growing.

For many years it has been recognised that an animal requires not only so much protein per day, but a certain quota of energy, and many attempts have been made to express this fact in intelligibie terms. Most of them have taken as basis the expression of the value of all the constituents of the diet in terms of starch, the sum of all the values being called the starch equivalent. This term is used by various writers in so many different senses that confusion has often arisen, and this has militated against its general acceptance. Perhaps the most usual sense in which the term is used is that in which it means the sum of the digestible protein multiplied by a factor (usually 1.94) plus the digestible fat multiplied by a factor (usually 2.3), plus the digestible carbohydrates. This, however, gives misleading values which are too high in concentrated foods and too low in bulky foods, the discrepancy being due to the larger proportion of the energy of the bulky foods which is used up in the much greater work of digestion which they require. Kellner and his school have devised a method which measures the starch equivalent by experiment, a much more satisfactory and practical method than any system which depends purely on calculation.

An animal or a number of animals are kept on a maintenance diet so that their weight remains constant. To this diet is added a known weight of starch, and the increase in weight observed. The animal or animals are then placed again on the same maintenance diet for some time, and then a known weight of the food to be tested is added, and the increase in weight again observed. The data thus obtained indicate that so many pounds of starch produce as much increase in live-weight as so many pounds of the food under experiment, from which it is easy to calculate how many pounds of starch are actually required to produce as much increase in live-weight as 100 pounds of the food under experiment. The starch equivalent thus found expresses an experimentally determined fact which is of immediate practical value in arranging a dietary, its value, however, depending on the accuracy with which it has been determined. Kellner and his colleagues have thus determined the starch equivalents of all the commonly used foods. Their values for concentrated foods, and other foods commonly used in Germany, have been determined with considerable accuracy, and with the method which has also been devised for defining the relation between the experimentally determined equivalent and the equivalent calculated from the analysis by means of a formula, they form by far the most reliable basis for arranging a feeding ration including such kinds of foods.

But roots, which form the staple of the diet of fattening animals in Great Britain, are not used on the same scale in Germany, and Kellner's starch equivalents for roots have not been determined with sufficient accuracy or under suitable conditions to warrant their use for arranging diets under our conditions.

This, and the fact that the term starch equivalent is so widely misunderstood, is no doubt the reason why the Kellner equivalent has not been more generally accepted in Great Britain. An advance will be made in the practice of feeding as soon as the starch equivalent of roots has been accurately determined under our conditions, when the Kellner equivalents will no doubt come into general use.

I have now reached the end of my survey. I recognise that it is very incomplete, and that I have been compelled to neglect whole subjects in which important work has been done. I venture to hope, however, that my words have not been altogether unprofitable. It is somewhat difficult to summarise what is in itself really nothing but a summary. Perhaps, however, I may be allowed to point out once more what appears to me to be the moral of the last twenty years of work in agricultural science.

The many practical fields and feeding tests carried out all over the country have demonstrated several very striking results; but, if they are to be continued with profit, more trouble must be taken to insure accuracy. Farmers are ready to listen. It behoves us more than ever to found what we tell them on accurate results.

Besides such practical trials, however, much has been done in the way of individual scientific work. The results thus obtained, as, for instance, Russell and Hutchinson's partial sterilisation of soils, Biffen's new wheats, and Beaven's pure Archer barley, are of practical value to the farmer as immediate as the most practical field trial, and of far wider application.

The following Papers were read :—

1. *German Forestry Methods. By* Professor Fraser Story.

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2. *Further Observations on the Fungicidal Action of Bordeaux Mixture. By* Professor B. T. P. Barker, *M.A., and* C. T. Gimingham, *F.I.C.*

In a previous paper the authors concluded that probably the most important, although not necessarily the only, cause of the fungicidal action of Bordeaux mixture is the solvent action which fungus cells under certain conditions are capable of exerting on the insoluble copper compounds of the spray fluid.

In continuation of the earlier work, it has been shown that germinating spores and the thin-walled cells of fungus hyphæ when in contact with or within a limited radius of particles of the copper compounds exercise solvent action and are killed by absorption of the dissolved copper. Similar results occur in the case of roothairs and the thin-walled external layers of cells of the roots of germinating seedlings. The extent of the action depends on the character of the cell-wall, apparently according to the degree of permeability.

In the case of apple leaves, the cuticle of the upper epidermis during spring and summer seems to be practically impermeable, and as a result no injury follows spraying so long as the cuticle constitutes a continuous uninjured covering to the leaf. If any injury causes a break in it or if a change in its character leading to greater permeability occurs—as appears to be the case in autumnal foliage—scorching due to injury of the thin-walled internal tissues follows owing to direct solvent action of exuded substances on the fungicide. While absorbed copper causes death of individual cells or local groups of cells in such cases, appreciable amounts of copper may be translocated from the affected areas to other parts of the plant without causing injury in transit. There is also evidence that copper slowly absorbed through comparatively difficultly permeable external walls may be diffused through the plant without visible injury to any cells.

As to the nature of the substances exercising solvent action, in the case of germinating seeds and the roots of young plants carbon dioxide is an active agent, but in addition other substances not at present examined in detail play an important part.

The physiological effect of the absorbed copper on the treated plant is under investigation.

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3. *A Peculiar Disease of Cereals and Roots and the Action of Sulphur and Lime. By* Walter E. Collinge.

The disease, which is locally known as 'maysick,' is most evident on wheat, and is probably due to bacteria that interfere with the nutrition of the plant.

This was described in some detail, together with experiments that had been made with a view to curing the disease. In this respect flowers of sulphur and unslaked lime have been found to be successful.

4. *The Growing of Linseed as a Farm Crop.* *By* DUNCAN DAVIDSON.

The growing of flax for fibre has been a feature of Irish and, to a less extent, of British agriculture for many years, but linseed as a farm crop is unknown to most farmers in this country. Experiments in the growing of linseed have been carried out on a limited scale in England and Wales during the last three years, and this year more extended trials are being conducted.

The main purport of this paper is to put forward some arguments in favour of linseed-growing; to describe the cultural requirements of the crop; and to consider the cost of production, probable yield, and money value of the crop on suitable land, as far as the limited experience and paucity of data at our disposal will admit.

The special value of linseed as a cream substitute for calves, its superiority as a fattening and 'finishing' food for older cattle, its ability to secure good 'condition' in horses, its unrivalled effect as a tonic for ailing stock, not to mention its excellence for sheep, is universally admitted by farmers. The increasing demand for linseed oil and the decreasing export of linseed have advanced the price of linseed and linseed cake during the last few years to a level which almost prohibits their use as stock foods, and the present fall in price can only be regarded as temporary.

Linseed is practically indispensable as a stock food, and its production at a reasonable cost becomes a pertinent problem. Can the British farmer grow linseed profitably? Experiments so far go to prove that 10 to 15 cwt. of linseed can be grown at the cost of about 6*l.* per acre on medium land, while we pay as much as 10*l.* for half a ton of linseed meal containing up to 10 per cent. of cheaper meal. Moreover, as a stock food the home-grown material is superior to the imported linseed, and it can be used instead of expensive linseed cake, and is a certain source of genuine linseed meal. The increasing demand for linseed oil, and the preference by the trade for oil from home-grown linseed, point to the possibility of growing linseed on a commercial scale in the near future.

For the linseed crop the texture, depth, and water supply of the soil, and the capacity of the subsoil to store water are of the greatest importance; and while clay, sandy and peaty soils have so far proved unfavourable, good crops may be grown on widely different types of soil.

The climate of England and Wales is quite suitable for the growth of linseed, as experiments in the North, West, and South-East of the country testify; and the influence of weather conditions on the crop may be ascertained by a comparison of the effect of the seasons in the last three or four years. The place of linseed in the rotation is practically optional, provided the crop does not appear too frequently on the same land. The flax crop is not grown on the same land oftener than once in seven years at least. In the U.S.A. and Canada linseed is chiefly grown as a first crop on virgin land, and in the other linseed-producing countries, except Russia, no fixed rotation is followed. Linseed is an excellent covering crop for 'seeds,' a useful substitute for spring corn, and an alternative crop for wheat, and may be followed by catch crops, and may itself be grown as a catch crop.

In preparing the land for linseed, special attention must be given to early tillage, the destruction of weeds, and the fineness and compactness of the soil. The most suitable manures for the crop have yet to be determined, as the results obtained in the case of flax crops are inconclusive. From ancient times flax has been regarded as an exhaustive crop, and it is traditional that flax 'draws the land,' but a comparison of the plant food materials required by the flax crop and those removed by other farm crops does not support this view. Flax is pulled and the soil is deprived of the stubble, whereas the linseed crop is cut, except when very short, and the stubble remains in the soil; and, moreover, the grain fed to stock on the farm enriches the manure heap. The most serious drawback to linseed-growing is the scarcity of good seed. Most of the

ordinary commercial linseed is quite unsuitable, owing to its mixed origin, impure condition, and low vitality. For linseed 1½ to 2 bushels of seed—a good sample has a bushel weight of 56 lb.—according to the variety, is sufficient, as it is desirable to encourage the branching of the plants; while for flax more seed is sown to secure plants with stems free from branches. It is not yet certain whether an early-sown crop gives a better yield. For the present the period from the middle of April to the middle of May is recommended as the best time to sow linseed. The seed may be broadcasted or drilled, preferably on a rolled surface, and should be lightly covered in. The breeding and selection of suitable strains of linseed—that is, those rich in oil and of good yielding capacity—is an urgent necessity, and the question of change of seed and the treatment of the seed as a safeguard against diseases must be gone into. Weeds must be rigorously excluded, especially dodder and charlock, by sowing pure seed on clean land and by weeding, as owing to the limited range of the foliage of the crop they develop more rapidly than in the case of other crops. The advantage of growing linseed after a 'root' crop is quickly realised on 'foul' land.

Linseed is unusually free from insect attacks, but the wireworm may do much damage to the young plants. Birds are often troublesome. The diseases known as 'yellowing' and 'wilt,' ascribed to various causes but most probably due to fungi, may do serious injury to the linseed crop, particularly the 'wilt,' which is supposed to give rise to 'flax-sick' soil. The contention that linseed has a detrimental effect on crops which succeed it is as yet not borne out in practice.

The ripening of linseed is indicated by the decaying of the leaves, the yellowing of the straw and capsules, and the gradual change in the colour of the seed, which should be bright, brown, and plump when ready for cutting. When 'dead' ripe the crop is almost leafless, and has a dull dark brown appearance, while the seed is a glossy deep-brown colour and rattles in the capsules when the plant is shaken. The crop must be cut before the latter stage is reached, or much loss of seed occurs in harvesting. The mode of cutting (if very short it may be best to pull the crop) depends on the length of straw, and whether the crop has 'lodged' or not. For small areas a hook or scythe may be used, but when the acreage of linseed is extensive the reaper will be employed. The crop must be thoroughly dried before being carried, as dampness is fatal to the quality of the linseed.

The flail may be used for threshing small quantities of linseed, although a little seed is unavoidably left in the straw. The ordinary threshing machine is not efficient, and a special machine worked by a farm gas, oil, or petrol engine is to be tried this year. When clean, straight, undamaged linseed straw is required, the capsules may be removed by rippling, and crushed to extract the seed. The usual winnowing machine, provided with special screens, will free the linseed from refuse, and the clean seed must be stored in a cool dry place. Special care must be taken to secure dryness during storage, as linseed is damaged very easily by moisture. The linseed chaff may be fed to dairy cows and breeding ewes, but it is unsuitable for young stock.

The disposal of the straw is the chief difficulty, but recent improvements in machinery have resulted in its use as a source of fibre for industrial purposes. It is a valuable packing and thatching material, and is useful as a bottom layer for stacks and covered stock-yards.

The cost of production on a well-managed farm of medium land should not exceed 6*l*. to 7*l*. per acre, and a yield of 20 to 30 bushels of grain and 25 to 35 cwt. of straw may be expected when a suitable variety is sown, which, having regard to the high price of linseed, linseed meal, and linseed cake, is a paying crop.

FRIDAY, SEPTEMBER 12.

The following Papers were read :—

1. *The Value conferred on Dung by Cake Feeding.* *By* A. D. Hall, *F.R.S.*

2. *The Artificial Incubating Establishments of the Egyptians.* *By* W. H. Cadman, *B.Sc., F.C.S.*

The art of hatching fowls' eggs by artificial heat originated in Egypt in very remote times and was introduced into Europe from Egypt as a result of observations made by some of the scientific members of Napoleon's expedition.

The Egyptians have long been famous for this practice and still successfully carry it out throughout the country on a large scale. The profession is traditionally transmitted from father to son, and is consequently confined to particular families. The secrets of the process are generally guarded with a religious zeal, and solemn oaths are taken not to divulge them. This largely accounts for the very imperfect descriptions of Egyptian incubators published up to date, and the entire absence of all details of working. The author has resided for the last eight years in close proximity to several of these establishments, and has been able to examine both the buildings and the details of working. The building is large, and usually contains several rooms in which the attendants live, in addition to the egg-ovens; it is generally rectangular in shape and constructed of sun-dried Nile mud bricks. The walls are of double thickness with layers of sand between. A vaulted passage divides the two parallel rows of ovens. Each egg-oven has a capacity of about 30 cubic metres, and consists of two cells or compartments, one above the other, communicating by an opening in the middle of the lower roof. There is also a dome-shaped opening in the upper roof for the escape of smoke. Each cell can be entered from the passage by an opening just large enough for a man to pass through. The buildings vary in size, usually containing from eight to twenty ovens each.

The incubators are worked for four or five months of the year only, in winter and in spring.

Method of Working.—The ovens are heated a few days before putting in the eggs by means of burning fuel on the floors and in the passage. Chopped bean-straw or dried cakes of cattle-dung serve as the fuel. After removing the ashes and smoke from the lower cells, the floors of these are covered with straw mats sprinkled with bran, and the eggs are piled on these mats; each oven takes about 7,000 eggs.

The proper temperature is maintained by adding glowing fuel to the troughs in the upper cells. The eggs are pushed by hand round the floor twice daily so as to be heated from above in rotation. This device of heating from above is presumably adopted in imitation of the processes that occur with the sitting hen. At the end of seven days the eggs are tested with olive-oil lamps and clear (*i.e.*, unfertile) ones removed. After eleven days all fire is removed, and the upper cell is cleaned, and for the last seven days half the eggs are transferred to the upper cells and placed on mats. During the last ten days the temperature is maintained by the heat given out by the chicks themselves as they develop within the egg. The temperature and aeration are regulated by attending to the roof openings and fuel supply. Thermometers are never used. Long experience enables the superintendent to tell the exact temperature necessary by placing the egg against the sensitive skin of his eyelid. The variation in temperature during the hatching period is very slight as shown on the temperature chart obtained by a self-registering thermometer. The period of hatching is twenty-one days, the same as required for natural incubation.

The chicks, as soon as hatched, are removed to the passage to dry and disposed of on the following day, no food being required.

The hen hatches without additional moisture and equally so the egg-ovens of Egypt. The relative humidity has been taken daily to show the hygrometric state of the air in the cells during incubation.

Chemical analyses of the gaseous products resulting from the fuel combustion have been made by the author, and the effects of these products in the egg-cells were discussed with reference to Dr. Bay's remarkable theory recently communicated to the 'Institut Egyptien,' viz., *that the presence of carbon dioxide is necessary during the incubation period and indispensable to the evolution of fœtal life.*

On September 14, 1911, there were 512 native chicken incubators in the

whole of Egypt, hatching about 120 million of chicks annually. The non-sitting instinct of Egyptian poultry is doubtless due to this old practice of artificial incubation. A large installation of American hot-air incubators run on modern lines at Alexandria has recently attempted to compete commercially with the native incubators, but has proved a complete failure.

The total quantity of eggs imported into the United Kingdom from all foreign and colonial countries now exceeds eighteen million great hundreds[1] per annum, valued at more than seven million pounds sterling. About nine hundred million eggs per year are consumed in London alone. The above facts emphasise the importance of developing the utility poultry industry by introducing hatching operations of a much larger magnitude than is possible with small modern incubators.

The possibility of utilising the simple Egyptian system, somewhat elaborated upon and refined, for commercial purposes in this country is suggested.

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3. *The Utilisation of Sewage in Agriculture.*
By Dr. J. Grossmann.

Some of the greatest industries of the present time owe their existence to the utilisation of by-products which at some time were considered a nuisance; and sewage, which is the largest by-product, may in like manner become a valuable commodity. The total value of the nitrogenous matter, phosphates, and potash compounds contained in its liquid part is equal to twenty million pounds per annum. The value of its solid matter, termed sewage sludge, is about two million pounds per annum, and the author has succeeded in designing a practicable method by which this amount can be made available. At present, the process only deals with the sewage of Oldham, a town of 150,000 inhabitants. It is based on the reasoning that the highly unsatisfactory results which up to the present have been obtained with sewage sludge in farming are attributable to the fact that it contains fatty matter due chiefly to soap and kitchen refuse, and that if these fatty matters, which render the soil impervious to water and air, and which by enveloping the active chemical ingredients prevent them from being dissolved, were removed, a residue of manurial value would remain. By the author's process the dried sludge is mixed with a small percentage of acid and subjected to the action of superheated steam, which carries off the fatty matters (which are condensed in water) and leaves an inodorous, brown powder, completely sterilised, which contains, on an average, 1.5 per cent. of nitrogen, 3 per cent. of phosphate of lime, and ·5 per cent. of potash, distributed in almost molecular state over from 30 to 40 per cent. of organic matter similar to humus, and mixed with a certain amount of carbon in an extremely fine state of division. The results obtained from the residue mixed with phosphates and potash compounds are beyond what might be expected from calculations based on the units of the active principles. The process does not add to the cost of sludge disposal, is automatic, and works day and night without a break and with only such labour as is required in attending to the fires under the drying machines and boilers, and to mechanical movements. There is no smell from any part of the apparatus, and the men do not handle the sludge from beginning to end, as everything is carried on in closed vessels.

The solution of the problem of sewage sludge disposal should place the much larger problem of the application of liquid sewage to farming within closer reach of solution. Up to the present, the tendency in sewage treatment has been to reduce the amount of sludge, as in practically every place it has been a source of great expense and nuisance. It is now possible, and even advisable, to produce more sludge, and by doing so to obtain better effluents with reduced purification plants. So far, the great drawback in sewage farming has been that the sewage has had to be used whether the land required it or not. With a system of removing the solid matter (including the fatty compounds) from sewage without extra cost, the efficiency of the sewage purification plant would be greatly improved, and arrangements could be made by which the sewage could be, at any time, either sent on the land or dealt with in the purification

[1] One great hundred = 120 eggs.

plant, and as the soil could take up more liquid matter without becoming water-logged, larger quantities of sewage could be used on a given area. The enormous strides which have been made in the last seventy years in engineering, chemistry, and agricultural science, the use of oil and gas engines, improvements in pumping machinery, the distribution of electricity, the improvements in motor traction, all seem to point to the fact that within a measurable distance we should be able to utilise, if not all, at any rate a considerable part of the sewage which is now wasted, by having, in connection with municipal sewage works, a system of irrigation which would enable farmers to draw upon the effluent when they can profitably use it on their land and that the time has arrived when experiments on a fairly large scale in that direction should be carried out; such experiments should be made at the cost of the Government, as neither corporations nor individuals can be expected to undertake such work, and it is to be hoped that when the recommendations of the Royal Commission on Sewage are acted upon, and a Central Authority appointed to deal with the sewage question, they will give their attention to this matter.

Joint Meeting with Section K on Problems in Barley Production.

(i) *Selection of Barley for Productivity.* *By* E. S. Beaven.

With any cereal crop the produce of dry grain on unit area is the sum of the following factors: (*a*) number of plants surviving on the area at harvest; (*b*) average dry weight per plant, which is the sum of (*b*1) average number of stems per plant, and (*b* 2) average weight per stem; (*c*) the ratio of the dry matter of the seed to the dry matter of the plant. A series of cultivations were described as a number of 'pure lines' of barley and also of the F 2 to F 6 generations of some hybrids which have been carried out at Warminster during the years 1900 to 1912 The objects have been: 1. To discriminate between genetic differences and those due to extrinsic conditions; 2. Reduction of the 'probable error' of differences in magnitude of the above factors, as between different races in order to obtain valid comparisons of productivity. The method adopted is an elaboration of the Hays centgener system. 3. Correlation of the several factors in successive generations. 4. Correlations of the several factors *inter se.*

Some provisional conclusions were arrived at with reference to the relative importance of the factors and especially with reference to the 'migration factor.' The application of the results obtained, more especially to methods of selection for productivity from the progeny obtained by the cross-fertilisation of different races, was discussed.

(ii) *Irish Barley Experiments*, 1901-1907. *By* John H. Bennett.

First efforts to improve Irish barley were commenced in 1899 by Mr. H. C. Sheringham, on behalf of the Irish Organisation Society, by means of quarter-acre plots for different varieties and different proportions of artificial manures. Mr. Sheringham continued to work under the Irish Department of Agriculture, constituted in 1900, and in 1901 the size of the plots was increased to two acres each, in order to provide for the subsequent separate malting and brewing by Messrs. Guinness of the produce.

Archer, Goldthorpe and Standwell barley were grown at four centres in 1901, at six centres in 1902, and at eight centres in 1903, also two-acre plots to test full artificial manuring versus none.

Archer proved best, Goldthorpe second, Standwell third, and the malting results confirmed this order. Artificial manures increased the yield without impairing brewing quality.

In 1904 Mr. Hunter succeeded Mr. Sheringham. Scotch Chevallier and Old Irish Barley were added and the two-acre experiments were grown on ten farms in five counties. The quarter-acre series was discontinued. The raising of pure seed of the different varieties was commenced.

In 1905 there were eleven centres in six counties occupying 150 acres, while Hallett's Chevallier was added at every centre.

In 1906 Danish Prentice Barley (proved best in Denmark and since found to be identical with Archer) was introduced. Hallett's was dropped owing to weak straw. There were twelve centres in seven counties. Danish Archer proved best, Irish Archer, Goldthorpe, and Scotch Chevallier following in the order named. The superiority of Archer barley after fifty-one tests during six years—its value per acre being 12*s*. above the next best, Goldthorpe—appeared manifest.

In 1907 the scheme of field plots was made to test Irish Archer barley further against Danish Archer, and also the possible deterioration of either by continuous growing in Ireland. Irish Archer raised from ears selected by hand in 1904 was compared with Danish Archer grown in Ireland in 1906 and with freshly imported Danish and English Archer. Both Danish Archers proved equal. Irish Archer showed improvement by selection, being very little below Danish. English Archer showed impurity, and was lower in yield than the others. Subsequent Irish experiments have confirmed the conclusions that productivity is improved by selection and that quality and yield are not affected by continuous growing in the same climate.

During these eight years both good and bad seasons were experienced, but the definite and consistent results obtained, causing the introduction of Archer barley for general use in Ireland, have brought about remarkable benefits. The quality of the barley has been improved in every way, a much larger proportion is available for malting and the yield per acre has also been increased.

(iii) *Barley-growing in Ireland. By* H. Hunter.

A description of the earlier experiments in barley-growing in Ireland and their results having been dealt with by Mr. Bennett, this paper was intended to describe the character and general results of selection and other later investigations.

It has been shown that Archer and Goldthorpe are more desirable varieties for cultivation in Ireland than those in general use prior to 1901. There are strong indications that while Archer is a more profitable barley on light land when judged over a series of years, Goldthorpe is best suited to heavier soils. Further, Goldthorpe is an earlier, and consequently on heavy soils and in most, but especially late seasons, a safer variety to cultivate.

In point of quality Archer and Goldthorpe proved superior to the barleys in cultivation, and an attempt was made to show how the standard of quality has been improved concomitantly with that of yield.

Before the introduction of Danish Archer into Ireland in 1906 the stock of Archer under experiment was the heaviest yielding variety of any of those that had been tested; the former barley, however, not only proved more prolific than the strain of Archer in use, but exhibited a more even growth and ripening in the field, and greater evenness in size and quality of grain.

Primarily, as a result of the difficulty in obtaining pure seed for field trials and the consequent unevenness of the crop when growing, selection experiments were commenced in 1904, and seed raised from 'group' selected seed and from single ears. The effect of these selections on the character of corn crops is dealt with, as also is the influence on the quality of the grain.

A characteristic of Archer of some disadvantage is its habit of late ripening. Attempts have been made to select a strain which is earlier ripening, and an account of these is given.

The field plots on which the earlier variety trials were conducted were two acres each in extent, sufficiently large to provide material for the malting trials conducted by Messrs. Guinness. In 1908 they were reduced to one acre, and have been continued at that figure ever since.

The rapid multiplication of distinct pure lines and hybrids necessitates an easier and less expensive method of initial quantitative testing. A system of small scale variety testing, in which each plot is one square yard, and repeated a large number of times, has been in operation at Ballinacurra for the past two years. These small scale plots not only yield general results of an extremely interesting character, but considerable data relative to some of the probable factors of yield have also been obtained and were discussed.

(iv) *The Precision of the Irish Barley Experiments. By* Dr. F. E. Hackett.

(v) *The Burbage Breeding Experiments. By* Major C. C. Hurst.

MONDAY, SEPTEMBER 15.

Joint Meeting with Section I.—See p. 669.

TUESDAY, SEPTEMBER 16.

The following Papers were read :—

1. *The Partial Sterilisation of the Soil by means of Caustic Lime. By* H. B. Hutchinson, *Ph.D., and* K. MacLennan, *B.Sc.*

The main line of work has been to determine the efficiency of caustic lime as a partial sterilisation agent for field conditions, but from the results obtained it would appear probable that a closer inquiry into the effects of lime and of chalk on field soils and of the general practice of liming would repay further investigation.

Various types of soils have been submitted to periodical chemical and bacteriological analysis and show great differences in their behaviour on treatment with caustic lime in different proportions and with chalk. The factor limiting bacterial activity and the proportion of ammonia and nitrate may be successfully removed by applications of caustic lime, but the possibility of a profitable adoption of the method in practice—with the exception of market-garden conditions—can only be decided after reference to special conditions, such as type of soil, intensity of cultivation, type of crop and prevailing prices. The action of lime may be regarded as being intermediate in character between that exercised by heat and mild antiseptics. The micro-flora and fauna of the soil are not affected to such an extent as by heat, but the amount of chemical change is much greater than that caused by antiseptics as carbon bisulphide and toluene.

After a certain incubation period, the length of which depends on the character of the soil and the amount of lime applied, soil bacteria begin to multiply rapidly and lead to large increases in the amount of available nitrogen. Below the partial sterilisation limit the production of food would appear to be due to initial chemical action of the lime in breaking down some of the more complex soil constituents, so that the total ammonia and nitrate are in some cases in proportion to the amount of lime applied. Above the partial sterilisation point this relation no longer holds.

The value of an addition of chalk depends largely on the amount of carbonate initially present in the soil and the character of the reserves of soil nitrogen. In some cases its action is considerable, whilst in others it is negligible.

Table showing the Effect of Caustic Lime and of Chalk on the Production of Ammonia and Nitrate in various Soils. (Parts per million of Dry Soil.)

Soil	Caustic Lime (per cent.)							Chalk (per cent.)
	0	0·1	0·2	0·3	0·4	0·5	1·0	1·0
Rothamsted . .	8	21	40	44	46	54	69	8
Chelsea . . .	31	36	41	49	57	59	75	33
Wobury (acid) .	12	29	45	48	54	60	35	49
Craibstone . .	23	18	27	35	44	49	90	33

Pot culture experiments with barley have been carried out, and show that with many soils large increases of crop may be obtained by the use of moderate applications of caustic lime. With some soils (garden soils, rich in carbonate) plant growth is adversely affected by larger doses, but the authors are not prepared at present to advance an explanation of the phenomenon.

Pot Cultures with Barley in Limed Soils.
Yields of Dry Matter (Untreated Crop 100).

Soil	Caustic Lime applied (per cent.)							Chalk (per cent.)
	0	0·1	0·2	0·3	0·4	0·5	1·0	1·0
Rothamsted .	100	209	224	300	276	199	14	101
Chelsea . . .	100	99	115	112	111	105	94	96
Craibstone . .	100	96	110	116	132	135	160	118
Millbrook . .	100	184	230	271	—	85	1·5	114

Co-operative action in field experiments on the comparative action of caustic lime and of chalk is greatly needed, in order that such questions as the partial sterilisation of field soils, the appropriate time of the year, and the alteration of physical conditions on crop production may be elucidated.

2. *Investigations on the Protozoa of Soil.* By T. Goodey.

This paper dealt with two pieces of work carried out to ascertain the part played by protozoa in the soil, and is the outcome of the theory advanced by Russell and Hutchinson, viz., that the protozoa in the soil act directly as a factor limiting bacterial activity, and therefore affect indirectly soil fertility.

The first investigation consisted of an attempt to get out from the soil, by a rapid method, the first protozoa to appear in a hay-infusion culture of soil. It was inferred that these would, in all probability, be the forms leading an active existence in the soil, if such were present. A method was finally devised by means of which the *ciliated* protozoa appearing first in such a culture were obtained quite quickly. These forms were chiefly *Colpoda*, and in no case did they appear until an hour and a half to two hours after inoculation. This period of time is practically the same as that taken for the excystation of *Colpoda* from its resting-cysts. Moreover, the protoplasm of these earliest-occurring forms contained no food vacuoles and resembled very closely in appearance that of recently excysted *Colpoda*. This suggested that they had come out from cysts on the addition of the soil to the hay-infusion. The conclusion drawn from these results was that the *ciliated* protozoa are only present in the soil in an encysted condition and cannot therefore function as the factor limiting bacterial activity.

The second investigation dealt with the effects of partial sterilisation on two old soils which had been stored in bottles for many years at Rothamsted, one since 1846 and the other since 1870. The former yielded no protozoa under cultural conditions, whilst the latter only gave amœba and flagellates as its protozoan fauna. A set of four bottles of each of these soils was put up and partially sterilised by means of volatile antiseptics, one bottle of each set being left untreated. Counts of bacteria were made over a period of about 240 days. It was found that the 1846 soil showed no phenomena which accompany a normal soil when partially sterilised. The bacteria in the untreated soil did not remain low in numbers, but on the contrary reached and maintained a higher figure than the bacteria of the treated soils.

The 1870 soil on the other hand showed the usual phenomena accompanying partial sterilisation. The untreated soil kept low in bacterial numbers whilst the treated soils showed high bacterial numbers. In the treated soils also the protozoa were killed off. The conclusion drawn from these experiments is that in the 1846 soil there is no factor limiting bacterial activity, whilst in the 1870 soil containing amœba and flagellates the limiting factor is present.

3. *The Weeds of Arable Land.*
By WINIFRED E. BRENCHLEY, *D.Sc., F.L.S.*

The distinction between weed and crop is very sharply marked where arable land is concerned. Weeds may be defined as 'plants other than those intended to be sown, which grow up naturally with the crop, and if unchecked prove exceedingly detrimental to the crop.' The weeds may spring either from seeds already in the soil or from seeds accidentally introduced with those of the crop.

Weeds are able to do damage to the crop in various ways :—

(1) They utilise much of the raw food material and water of the soil, so lessening the supply available for the crop.

(2) They steal light, as when they grow luxuriantly they overshadow the crop plants, and so hinder carbon assimilation.

(3) The weed seeds render the crop seeds impure, and so entail much expense in the special processes of cleaning and separating thus rendered necessary.

(4) Weeds provide harbourage for various insect and fungus pests which would either be entirely absent or at least far more easily dealt with if the ground were clear of alien plants.

An examination of the relations existing between the weeds, crops, and soils, carried on in various parts of England, shows that arable land forms a definite plant habitat, and carries a distinct weed flora which varies somewhat according to local conditions. In dealing with such a problem as this, the utmost care is needed in the interpretation of results, as so many factors come into play. Differences in climatic conditions, methods and times of cultivation, systems of manuring, &c., all play their part in influencing both the composition of the weed flora and the balance of its component species.

On *clay* soils the weed flora is less rich in species than is the lighter loam, and though several plants have a decided preference for heavy land, yet no species can be said to be 'symptomatic' of clay, occurring on such soil and nowhere else.

Sandy soils possess a much more characteristic weed flora, as they are colonised by a great diversity of plants, a good many species being definitely associated with light soils. Such plants as spurrey, corn marigold, sheep's sorrel, and knawel appear to be characteristic of sandy soils which are deficient in chalk, 'sour' soils.

Chalk provides quite a peculiar habitat for weeds, partly because of its texture and partly because of its chemical composition, as so much calcium carbonate is present. The weed flora of the chalk is relatively very rich in species, some of which are markedly characteristic of such soil.

It is now evident that a definite association exists between the species of weed plants and the soil on which they grow. This association may be either

(*a*) *Local*, when a weed is symptomatic of a certain soil in one district, but is not so exclusively associated with it in another.

(*b*) *General*, when a certain species is symptomatic or characteristic of the same type of soil in different districts.

The nature of the crop also plays its part in determining the weed flora. This influence is partly due to the different habit of growth of such crops as cereals, roots and leguminous plants, but it is probably more largely the result of the varying methods of cultivation applied to the crops—*e.g.*, root crops are so thoroughly cultivated throughout their season of growth that comparatively few species of weeds can hold their own, whereas leguminous plants cannot be hoed during growth, so that many weeds have an opportunity to flourish if they can withstand the competition of the crop.

It is evident that the problem of the weeds of arable land must be approached with a perfectly open mind, recognising that a relation obtained in one place does not necessarily hold good in another. Yet when all the factors influencing the flora come to light it seems probable that the apparent contradictions will find a satisfactory explanation and prove to be different expressions of a well-defined order.

4. *Nitrification in some Pasture Soils.* *By* C. T. Gimingham, *F.I.C.*

The author gave an account of some observations on the processes of ammonification and nitrification in some pasture soils containing a high percentage of organic matter and very little carbonate. It is known that nitrification is reduced to a minimum in a pasture soil rendered acid by the continued use of ammonium salts as manure; and an investigation has been made of the behaviour in this respect of soils naturally acid or in process of becoming acid. The soil chosen for most of these experiments was one apparently intermediate between a true 'moor' and a true 'fen' soil. It is very dark in colour, contains between 30 per cent. and 40 per cent. organic matter, and only traces of carbonate, but the soil water is neutral in reaction. It behaves as an acid soil in that, when seeded into a culture solution containing glucose, with ammonium chloride as the only source of nitrogen, a growth of moulds appears and the culture becomes distinctly acid. On the other hand, the soil itself is capable of bringing about rapid nitrification. The plan adopted was to follow the fate of the nitrogen in peptone added to the soil beyond the ammonia stage and to determine also the nitrates formed. It was found that nitrification sets in almost at once and proceeds very rapidly. Ammonium sulphate is also quickly nitrified, though the soil very soon takes on a faintly acid reaction.

Figures were given of a series of determinations of ammonia and nitrates over a considerable period in portions of soil to which peptone was added; these were compared with similar figures obtained from normal soils and from soils naturally acid. Other details of the behaviour of these soils were given.

A note on the use of 'nitron' for the determination of nitrates in soil extracts was appended.

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5. *The Effect of Soluble Humates on Nitrogen Fixation and Plant Growth.* *By* Professor W. B Bottomley, *M A.*

The observations of Heinze, Krzemieniewski, and others on the influence of soluble humates on nitrogen-fixing bacteria suggested the possibility of using a material rich in soluble humates as a medium for introducing cultures of nitrogen-fixing bacteria into the soil. It was thought that such a medium might also benefit the nitrogen-fixing organisms already present in the soil.

It has been found that the insoluble humic acid which is present in large quantities in peat can be readily converted into soluble humate by the action of certain aerobic soil bacteria. Peat after treatment with these organisms is sterilised and then inoculated with a culture of nitrogen-fixing organisms. This prepared peat can then be used for soil inoculation, either by direct application to the soil, or preparing from it a culture solution.

A mixture of 9 oz. of poor garden soil and 1 oz. of prepared peat after seventeen days' incubation at 26° C. gave the following results:—

Soil+sterilised prepared peat	(*a*)	·717	grm. N per 100 grms. soil.
	(*b*)	·709	,, ,, ,, ,,
Soil+active prepared peat	(*a*)	·792	,, ,, ,, ,,
	(*b*)	·789	,, ,, ,, ,,

An average gain of 77 mgrms. of N per 100 grms. soil.

A culture solution was obtained by mixing 2 grms. of the prepared peat and ·5 grm. of sugar in 100 c.c. of distilled water, and incubating at 26° C. for twenty-four hours. A mixture of 12 oz. of soil and 75 c.c. of this culture solution, after seventeen days' incubation at 26° C., analysed as follows:—

Soil+sterilised culture	(*a*)	·241	grm. N per 100 grms. soil.
	(*b*)	·251	,, ,, ,, ,,
Soil+living culture	(*a*)	·348	,, ,, ,, ,,
	(*b*)	·338	,, ,, ,, ,,

An average gain of 97 mgrms. of N per 100 grms. soil.

Pot experiments in the greenhouse and plot experiments in the open showed that the prepared peat, in addition to its effect on nitrogen fixation, has a direct influence on promoting plant growth. This is probably due in part to the

presence of ammonium humate, which, in addition to being a direct source of nitrogen for plants, stimulates their root development in a remarkable manner.

At Chelsea Physic Garden a plot of radishes watered once with an extract of prepared peat gave an increase of 54 per cent. over the untreated plot. At Eton School Gardens plots with prepared peat, compared with plots with farmyard manure, gave the following increases :—Lettuce, 27 per cent.; turnips, 23 per cent.; potatoes, 41 per cent. Pot experiments at Chelsea on wheat, barley, and oats showed that the prepared peat promotes tillering.

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6. *The Life History of* Eriophyes ribis *Nab.* *By* Miss A. M. Taylor.

Comparison was made in this paper of the life-history of *Eriophyes ribis* on *Ribes nigrum* and *Ribes Grossularia* respectively as host plants.

With Ribes nigrum *as host plant.*

The embryonic true leaves of the bud are attacked by the mite, and the bud develops into a 'big-bud.' No injury is caused, however, to the foliage of the tree.

The migration of mites from infested buds to new plant-food is carried out mainly by the agency of the wind.

Observations show that *Eriophyes ribis* respond to the stimulus of temperature by raising themselves to an erect position. When this position is taken, successful distribution by wind occurs.

With Ribes Grossularia *as host plant.*

The scale leaves of the bud only are attacked, and no 'big-bud' is formed.

It is suggested that the structure of the buds of *Ribes Grossularia* is such that the mites cannot penetrate into the true leaves of the bud. The injury caused by the mite to *Ribes Grossularia* is confined to the foliage of the affected tree.

Distribution by wind is not of general occurrence, migration being mainly carried out by the mites crawling from the infested bud to the expanding leaves.

It is probable that infection from *Ribes Grossularia* to *Ribes nigrum* takes place.

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7. *Partnership in Agriculture between Landlord and Tenant.* *By* Sir Richard Paget, *Bart.*

Agriculture in England at the present time, save in quite exceptional cases, is conducted on uncommercial lines. The ordinary landlord and tenant agreement secures no community of interests between the parties, no division of profits, and no opening for outside capital. Farming as a profession is consequently limited to the relatively small class of farmers who have sufficient capital of their own.

If agriculture wants more capital, in order that it may be carried on in its most profitable manner, it must be brought within the pale of the industries, and must offer to capital a fair share of the profits.

Farming on a share of produce in lieu of rent—such as the métayer system on the Continent, or 'farming on shares' in Canada, the U.S.A., and Australia —certainly gives an opening for capital and enables a farmer to operate without capital of his own, but it has the objection that the landlord is only interested in the yield of the crop (of which he gets a half, a third, or other agreed proportion), not in the cost of producing it, since the cost of labour falls on the tenant. The interests of the parties are not identical and the system does not tend to encourage the most intensive culture.

The ideal system would appear to be a business partnership wherein the landlord invests the land, the tenant invests what capital he can, and the balance necessary for the most efficient cultivation is invested by the landlord, or it might be borrowed by the partnership on the security of its assets and the guarantees of the partners.

The landlord is credited, for the purpose of division of profits, with the agricultural value of the land, and the tenant is credited with a nominal capital representing the capitalised value of his skill and services.

In estimating the amount of tenant's capitalised value, it is assumed that, if the partners each provide half the cash capital, the tenant's share of profits in return for his services should be equal to the landlord's in return for his land and for such services as he may be able to render to the partnership.

If, therefore, the land is valued at, say, 4,500*l.*, the tenant would also be credited with 4,500*l.* as representing the capitalised value of his services.

If the capital required were 1,500*l.*, and, in the first instance, the whole of it were supplied by the landlord, the landlord would be credited with 4,500*l.* plus 1,500*l.*, equals 6,000*l.*, as against the tenant's 4,500*l.*, and would, therefore, receive four-sevenths as against three-sevenths of the divisible profits.

In estimating profits, all expenses for repairs, tithes, taxes, and insurance, &c., are charged to the partnership.

The tenant is given the right to invest from time to time up to the total amount of the cash capital, thus buying out the landlord's capital interest, other than his interest in the land. The landlord would then receive three-sevenths of the profits, and his money back, while the tenant would receive the remaining four-sevenths of the profits.

Where the landlord was willing to sell the freehold, he might be bought out altogether.

A form of partnership agreement to carry out these proposals has been prepared by Mr. T. G. Spyers, barrister-at-law, of Lincoln's Inn.

To secure to both parties the benefits of landlord and tenant legislation, and to meet the difficulties of 'limited ownership' in the case of tenants for life, it is provided that the landlord first grants the tenant an ordinary agricultural lease—either for a long term or from year to year—and that the parties then enter into partnership, bringing in their respective interests in the lease as partnership assets. The fixed rent secured in the lease is remitted by agreement during the partnership.

On the death of either partner, the partnership is dissolved and the assets divided, but the lease is only determined by the death of the tenant.

In the case of a long lease, the tenant may be under obligation to give an option to the landlord's successor (on the death of the landlord) to enter into partnership on the same terms.

Comparing the proposed partnership tenancy with the present system of tenure, the partnership system should tend as follows:—

(1). To make agriculture an industry comparable with other industries.

(2). To encourage commercial methods, the keeping of proper accounts, and more scientific methods.

(3). To give to agriculture the advantage of better credit and cheaper money, by the association of the landlord's credit with that of the farmer.

(4). To encourage landlords or other capitalists to invest in agriculture.

(5). To enable properly trained farmers to start farming without capital of their own, and to give them an opportunity to invest their savings in their farms.

(6). To facilitate systematic profit-sharing with labourers on farms.

(7). To give landlords a business interest in their farms and so place them in the position to secure co-operation between farmers, to obtain information and technical advice, and generally to use their intelligence and influence for the good of the industry.

APPENDIX.

THIS INDENTURE is made the day of 1913, between of in the County of (hereinafter called the Landlord) of the one part and of in the County of (Farmer) (hereinafter called the Tenant) of the other part WHEREAS this Indenture is supplemental to an Indenture of Lease (hereinafter referred to as the Lease) of even date with and made between the same parties and in the same order as the parties to this Indenture AND WHEREAS the Landlord is desirous of assisting the Tenant to cultivate the farm and premises (hereinafter referred to as the Farm) comprised in and demised by the lease in the best and most efficient

manner now THIS INDENTURE WITNESSETH that in consideration of the premises the Landlord and the Tenant hereby mutually covenant and agree as follows :—

1. The Landlord and the Tenant will become and remain partners in the business of cultivating the farm from the day of the date hereof under the style or firm of subject nevertheless to determination as hereinafter provided.

2. Either partner may determine the partnership hereby constituted at any time on giving not less than calendar months' previous notice in writing to the other partner of his intention in that behalf and at the expiration of such notice the partnership shall determine accordingly.

3. The business of the partnership shall be carried on at the Farm.

4. The capital of the partnership shall consist of such sum or sums of money as shall from time to time be required for cultivating the Farm to the best advantage and shall be contributed by the partners in equal shares or in such other shares as may from time to time be agreed on between them.

5. The stock and plant belonging to the farm at the commencement of the partnership the particulars whereof are specified in the Schedule hereto shall be valued by a competent valuer and shall become the property of the partnership, and the value of the stock and plant mentioned in the first part of the said Schedule shall be credited to the Landlord in the books of the partnership as part of the capital brought in by him and the value of the stock and plant mentioned in the second part of the said Schedule shall be credited to the Tenant in the said books as part of the capital brought in by him.

6. The Tenant his executors or administrators shall if and when required so to do by the Landlord and at the cost of the firm duly assign the farm and premises to the Landlord and the Tenant as joint tenants as part of their partnership estate for all the residue then unexpired of the term of one year from the day of and so on from year to year granted by the lease subject thenceforth to the payment of the rent thereby reserved and the performance and observance of the covenants by the lessee and conditions therein contained and in the meantime and until such assignment as aforesaid shall have been made and executed shall hold the farm and premises in trust for the Landlord and the Tenant in joint tenancy as part of their partnership estate and so that if the partnership shall be determined otherwise than by reason of the death of the Landlord it shall be lawful for the Landlord to appoint a new trustee in his place.

7. The Landlord will at all times during the partnership so long as he shall be solely entitled to receive the rent reserved by the lease remit the same and if the right to receive the same shall at any time during the partnership become vested in any other person or persons whether jointly with the Landlord or otherwise will at all times thereafter during the partnership keep the partnership fully and effectually indemnified against the same.

8. The Bankers of the partnership shall be Messrs. or such other bankers as the partners shall from time to time determine and all monies and securities belonging to the partnership except such monies as are required for current expenses shall be paid into and deposited with the said Bank.

9. The Landlord shall not be required to attend to the management or cultivation of the farm and shall not sign the name of the firm. But the Tenant shall at all times during the partnership devote the whole of his time and attention to the farm and diligently and faithfully employ himself therein and carry on the same for the greatest advantage of the partnership and in accordance with the covenants on the part of the lessee and conditions contained in the lease. And the tenant shall at all times during the partnership unless expressly authorised in writing by the Landlord not to do so reside at the farmhouse on the farm in accordance with the covenant in that behalf contained in the lease but free of the rent thereby reserved and covenanted to be paid and free also from the rates taxes assessments and expenses of insurance and other outgoings hereinafter covenanted and agreed to be paid out of the receipts and earnings of the farm.

10. At all times during the partnership each partner shall be entitled to be supplied with such portion of the produce of the farm as shall be reasonably necessary for his personal use and consumption at the current wholesale price

of such produce and he shall be debited with such price accordingly in the books of the partnership as if the same were a drawing in anticipation of his share of the nett profits of the farm.

11. The expenses of repairs alterations and improvements and insurances against loss or damage by fire or otherwise of or to the said farmhouse and any buildings from time to time belonging to or used for the purposes of the farm and any crops cattle or stock so belonging or used and all rates taxes tithes assessments and other outgoings for or in respect of the farm and the salaries wages and shares of profits for the time being payable in respect of services to all persons employed on or in connection with the farm and all expenses losses and damages which shall be incurred in carrying on the farm or anywise relating thereto shall be paid out of the receipts and earnings of the farm and in case of deficiency thereof then by the said partners in equal shares or in such other shares as may from time to time be agreed upon between them.

12. The partners shall be entitled to the nett profits of the farm after making the payments last aforesaid in the same shares and proportions as their respective shares in the capital of the partnership for the time being and such nett profits shall be divided between them as soon after the end of each year of the partnership as the general annual account shall have been taken and settled as hereinafter provided, and for the purposes of this clause each partner shall be credited in the partnership books with the nominal sum of as part of the capital contributed by him in addition to the value of the stock and plant to be credited to him as mentioned in clause 5 hereof and in addition to any sum or sums of money which shall from time to time have been actually contributed by him for cultivating or otherwise for the purposes of the farm but it shall be lawful for the Tenant on or at any time within one calendar month after the day hereinafter fixed for taking the said general account in every year of the partnership to pay to the Landlord all or any part of the moneys which shall for the time being have been actually contributed by the Landlord for cultivating or otherwise for the purposes of the farm (but so that not less than be so paid at any one time) and the Landlord shall accept such payment and thereupon the share of the Tenant in the said partnership shall be proportionately increased and the share of the Landlord therein shall be proportionately reduced.

13. At any time after the day of in every year during the partnership the Landlord shall be at liberty to draw and to be paid in anticipation of his share of nett profits and to be accounted for at the next yearly division of profits such a sum as shall be equivalent to half a year's interest at the rate of four per cent. per annum on his share in the capital of the partnership for the time being and the Tenant shall be at liberty by monthly drawings or otherwise to draw in anticipation of his share of nett profits and to be accounted for at the next yearly division of profits sums not exceeding during such year but in case in any year the amount so drawn out by either partner shall on taking the general account be found to be in excess of his share of the nett profits then immediately after such account shall have been taken and settled the excess so drawn out shall be refunded without interest.

14. On the day of and on every subsequent day a general account shall be taken of the assets and liabilities of the partnership and of all dealings and transactions of the partnership during the then preceding year or in the case of the first of such accounts since the commencement of the partnership and of all matters and things properly comprehended in farm accounts and in taking such account a just valuation shall be made of all items requiring valuation. Such general account shall be entered in a book which shall be signed by both the Tenant and the Landlord or his Agent duly authorised in that behalf and when so signed shall be binding on both the partners, save that if any manifest error shall be found therein and signified by either partner to the other within six calendar months' after such signature the same shall be rectified.

15. Upon the determination of the partnership a full and general account of the assets liabilities and transactions of the partnership shall be taken and the assets and property of the partnership shall belong to the partners in the shares in which they are respectively entitled to the profits of the partnership subject

first to the discharge of the partnership debts and liabilities and secondly to the repayment to each of the partners (but without interest) of any sum or sums of money from time to time contributed by them respectively to the capital of the partnership.

16. If during the continuance of the partnership or at any time afterwards any dispute difference or question shall arise between the said partners or their representatives touching the partnership or the accounts or transactions thereof or the dissolution or winding up thereof or the construction meaning or effect of these presents or anything herein contained or the rights or liabilities of the partners or their representatives under these presents or otherwise in relation to the premises then every such dispute difference or question shall be referred to two arbitrators one to be appointed by each partner or their umpire pursuant to the Arbitration Act 1889 or any statutory modification or re-enactment thereof for the time being in force.

EVENING DISCOURSES.

FRIDAY, SEPTEMBER 12.

Explosions in Coal Mines and the Means of Preventing them. By Sir HENRY CUNYNGHAME, *K.C.B., Chairman of the late Royal Commission on Mining Accidents and of the Eskmeals Dust Explosions Committee.*

The object of the lecture was briefly to outline the nature of the experiments carried on at the Government testing station at Eskmeals, in Cumberland.

It has been proved that coal-mine explosions were generally due, not to gas, but to clouds of the fine coal-dust which, when raised into the air, made it explosive.

Methane, or fire-damp, the gas usually found in mines, when exploded with air gives rise chiefly to carbonic acid and steam.

But coal-dust, when exploded with air, produces in addition a large quantity of carbon-monoxide.

This gas is very poisonous. Hence coal-dust explosions are usually followed by the spread of a poisonous gas throughout the galleries of the mine. As a result, when a large explosion occurs, it is found that almost all the men have been killed, not by explosive violence but by the painless poison of carbon-monoxide.

It has been observed that coal-dust explosions usually stop short at places where, in addition to the coal-dust present, there was also a considerable quantity of rock-dust.

What appeared to be the case was, that when the explosion stirred up the coal-dust, it raised into the air the stone-dust also.

This, however, had a marked effect in preventing the coal-dust from exploding.

Works on a large scale exist at Eskmeals in which experiments were made to test how the stone-dust was necessary to make any given quantity of coal-dust inexplosive.

It has been found that this quantity is about 50 per cent. of the total dust present, whence it may be concluded that if that quantity is present in the dust of any mine, that is to say, if the roadways contain as much powdered inert dust as they do fine coal, it is almost impossible, or at least very unlikely, that an explosion can occur.

Experiments were shown illustrating the explosive character of coal-dust, and the effect of stone-dust mixed with it in reducing the inflammability of coal-dust.

TUESDAY, SEPTEMBER 16.

Missing Links among Extinct Animals. By DR. A. SMITH WOODWARD, *F.R.S.*

Although the world of life, as it exists to-day, bears many marks of the changes it has undergone during its past history, most of these are so difficult of exact interpretation that it is still necessary to depend upon fossils for a real knowledge of the facts. Most of the links in the chain or network of life died out long ages ago, and the few of importance which survive are so

much changed from their original condition that they sometimes suggest false conclusions. Although the geological record is so imperfect, it is therefore the most hopeful source of information concerning the origin and relationships of the various forms of life around us.

The first important discovery which drew general attention to fossils in this connection was that of the long-tailed bird, *Archæopteryx*, in the Upper Jurassic Lithographic Stone of Bavaria. At the present day there are no links between birds and the reptiles from which they appear to have been derived; but *Archæopteryx* forms a distinct link, and it dates back to the period when we may suppose that birds were just coming into existence.

The next remarkable step which attracted wide notice was Prof. O. C. Marsh's discovery of the genealogy of the horse in the Tertiary rocks of North America. He and Prof. Huxley showed how the modern one-toed horse, adapted for rapid motion over hard ground and for feeding on dry vegetation, could be traced back gradually to small four-toed ancestors which lived in marshes on succulent food. Later discoveries showed that camels, cattle, pigs, elephants, and, in fact, most of our familiar larger animals, might be traced back to small marsh-dwellers which could only be regarded as common ancestors.

These genealogies seemed fairly simple, but, as studies proceeded and discoveries multiplied, the subject proved to be much more complex than was at first suspected. The remains of rhinoceroses, for instance, of several successive geological ages, have been found both all over the Old World and in equal abundance over North America. They can be traced back to the usual common group of little marsh-dwelling ancestors; but, as shown by the researches of Osborn and Abel, there are obviously so many separate lines of descent, both in the Old World and in North America, that it seems almost impossible to unravel them. In the Old World the successive links in each of these lines gradually acquired the characteristic horns, and the rhinoceroses have continued to flourish exceedingly, at least in the warmer regions. In North America, on the other hand, for some curious undiscovered reason, they all died out when the growth of their horns was only just beginning.

Among links more recently discovered, none are more interesting than those between the lung-breathing sea-animals and their land-ancestors. For many reasons, there can be no doubt that the whales and porpoises originated at the beginning of the Tertiary period from mammals which at that time lived on the land. Recent discoveries in the lower Tertiary rocks of Egypt actually show that the whales of that date had a skull and teeth almost identical with those of some of the contemporaneous land-dwelling flesh-eaters; and when the rest of the skeleton is found it will almost certainly prove to be much less completely adapted for sea-life than that of the whales and porpoises of to-day.

This passage of land animals to a life in the sea has occurred several times. In Triassic rocks we are now beginning to find the semi-aquatic ancestors of the Ichthyosaurs and Plesiosaurs, which lived in all seas during the age of reptiles. We shall soon be equally successful with the ancestry of the sea-crocodiles, Mosasaurs and Champsosaurs, in successive later periods of the same great age.

The repeated evolution of animals of the same general shape and habit from a successive series of distinct ancestors is a very remarkable and significant phenomenon. In fact, the more links in the chain of life we find among fossils, the more evident does it become that there are some very definite laws or principles underlying the changes we observe, and that they have remained the same through all geological time. There is good reason to believe that races of animals have a natural term of life just as individuals are limited, and that if circumstances allow them to follow their complete career they exhibit stages which may be appropriately named youth, maturity, decline, and old age. The case of the chambered shells, known as ammonites and their allies, may be cited. We have reason to infer that they began in early Palæozoic times as straight shells; then they became curved and loosely coiled; next closely coiled; next repeating these processes in reverse order, and finally many of them ending as straight shells. The same progress from youth to second childhood is seen when the Dipnoan mud-fishes are traced through geological time: the latest survivors of the race are eel-shaped, just as their earliest members are supposed to have been. The existing true eels are another example of fishes in their

dotage, and we do not begin to find their normally fish-shaped ancestors until we go so far back as the Chalk.

It is also curious to note how close is the parallelism in some cases between the history of a race in geological time and the individual life-history of one of its latest members. The deer, for instance, had no horns or antlers before the Lower Miocene period; but since that time the successive species have gradually acquired antlers of increasing size and complexity, and those of some of the Pleistocene and later deer were so immense that they probably helped in the extinction of these animals. Exactly similar stages are passed through in the individual life-history of the common stag at the present day: when born it has no antlers, in the second year they are a pair of simple prongs, while in each succeeding year they become increasingly large and complex.

In fact, when any particular part of an animal begins to grow to a larger size, this growth tends to continue long after it appears to attain its special usefulness. Sometimes this leads to fundamental changes which turn the overgrowth from a burden to a decided advantage. For example, as soon as warm-blooded quadrupeds (mammals) appeared, the brain in these animals tended to grow large and complex. So long as there were no higher back-boned animals than reptiles the brain always remained insignificant in size. Among mammals this enlargement was obviously of some importance, because whenever members of this group grew large or showed special adaptations to a peculiar mode of life without a corresponding development of the brain they soon died out. Thus, our horses, cattle, lions, dogs, and so forth have only survived because the changes in the efficiency of their brain have kept pace with the special changes in the rest of their body. At the same time, during the whole of the Tertiary period, while these correlated changes in brain and body were taking place in the majority of mammals, one group remained as forest-dwellers. In them the skeleton, and presumably most of the soft parts, underwent practically no change, while the brain alone developed in size and efficiency. The little lemur-like animals of Eocene times thus passed gradually into the comparatively large apes of the Pliocene. Compared with the rest of the body, the brain tended to be overgrown, and it seems reasonable to suppose that this overgrowth eventually led to the complete domination of the brain which is the special characteristic of man. As soon as an animal could feed and defend itself by craft, its teeth and other primitive weapons would degenerate.

We have long been looking for the links that are missing in this hypothetical chain connecting man with the early forest animals, because, apart from adaptation to an upright gait, his skeleton is practically identical with theirs. We have looked for creatures with an overgrown brain and ape-like face, but hitherto without real success. The scientific world has therefore welcomed with great interest Mr. Charles Dawson's recent discovery of the skull and mandible of *Eoanthropus dawsoni*, the most primitive human being ever seen. The gravel in which it was found at Piltdown, in Sussex, dates back to the geological period when we might expect the earliest men to be just appearing; and the circumstances of its discovery leave no doubt that it was contemporaneous with the very rude flint implements which were lying in the same deposit near it.

When I first planned this lecture, I intended to speak at greater length and with fuller illustrations of the interesting general principles to which I have alluded, and then apply them to discuss the meaning of this latest missing link among extinct animals. The very conclusion as to its being a missing link, however, has been so much disputed lately in the newspapers that I am compelled to spend some time in a digression to assure you first of the facts. In my original description and interpretation of Mr. Dawson's discovery I stated that the skull of *Eoanthropus*, though typically human, was as low in brain-capacity as that of the lowest existing savages, while Prof. Elliot Smith asserted that the brain itself, as shown by the cast of the cavity, was of a more primitive kind than any human brain he had previously seen. I also concluded that, as the lower jaw exhibited so many ape-like characters, it must have been furnished in front with ape-like teeth, including enlarged

interlocking canines. Prof. Arthur Keith, on the other hand, has now made a new restoration of the skull to show that its brain capacity must have been larger than that of the average existing civilised man. He has also reconstructed the lower jaw to prove that its teeth were in all respects human, without any enlargement or interlocking of the canines. The results of the palæontologist are thus totally at variance with those of the human anatomist, and *Eoanthropus* cannot be discussed until the facts are settled.

Fortunately, Mr. Dawson has continued his diggings during the past summer, and, on August 30, Father P. Teilhard, who was working with him, picked up the canine tooth which obviously belongs to the half of the mandible originally discovered. In shape it corresponds exactly with that of an ape, and its worn face shows that it worked upon the upper canine in the true ape-fashion. It only differs from the canine of my published restoration in being slightly smaller, more pointed, and a little more upright in the mouth. Hence, we have now definite proof that the front teeth of *Eoanthropus* resembled those of an ape, and my original determination is justified.

It may next be questioned whether the ape-like mandible belongs to the skull. We can only state that its molar teeth are typically human, its muscle-markings are such as might be expected, and it was found in the gravel near to the skull. The probabilities are therefore in favour of its natural association. If so, it is reasonable to suppose that the skull will prove to be that of a very lowly kind, not that of a highly civilised man. I have accordingly made a new study of the specimen with the special help of my colleague, Mr. W. P. Pycraft, and I find that the only alteration necessary in our original model is a very slight displacement of the occipital and right parietal bones which Prof. Elliot Smith pointed out to us when he made his first studies of the brain. Both behind and in front I correctly identified the internal groove for the upper longitudinal blood-sinus which marks the middle line of the roof of the skull; and the reason why my adjustment of the occiput was not exact at first is, that on the hinder part of the parietal region of the skull-roof I noticed a longitudinal ridge which I supposed to be truly median, while the extraordinarily unsymmetrical development of the brain seemed to have pushed the longitudinal sinus at that part slightly out of its normal place. The change, however, only opens the top part of the skull behind to an extent of three-quarters of an inch, and there are compensations elsewhere through the necessary readjustments, so the total brain-capacity remains nearly the same as that I originally stated, well within the range of the smallest human brains of the present day. I have submitted our new brain-cast to Prof. Elliot Smith, who will shortly describe it in a memoir for the Royal Society, and he permits me to add that he finds it, in all essential respects, correct.

Eoanthropus may therefore be regarded as one of the links in the chain of the human race which has hitherto been missing, and we may proceed to consider what it means. A single isolated specimen cannot be said to prove much, but at any rate it admits several interesting suggestions.

In the first place, it must be remarked that Mr. Dawson's careful researches have conclusively proved the minimum geological age of the fossil. It is certainly the oldest typically human skull ever found, for it cannot be of later date than the early part of the Pleistocene period. It therefore seems to show that Prof. Boyd Dawkins and Prof. Gaudry were right when they said, many years ago, that our knowledge of the evolution of the Tertiary mammalia prevented our expecting to find fully-developed man in any geological formation earlier than the Pleistocene. In *Eoanthropus* we have a human being with a distinct remnant of ape-like ancestors in his jaws; and in the human mandible, probably of the same period, found near Heidelberg, we have a slightly more advanced stage with teeth which are distinctly human. When the Pliocene forerunners of these species are found, they will probably fall rather into the category of apes than of man.

Next in connection with the remarks I have made about the evolution of the brain in mammals, it is interesting to notice that the brain of *Eoanthropus* makes a much nearer approach to that of modern man than his face. It therefore appears that the excessive development of the brain preceded the

loss by the mouth of its function as a weapon. Increase of intelligence removed the necessity for so much brute force, and the face then became reduced in size, while the familiar weakness of the jaws of man was the result.

Finally, *Eoanthropus* may be considered from another point of view to which I have directed attention—the frequent parallelism between the life-history of a modern individual animal and the geological history of the race to which it belongs. If we compare the Piltdown skull with that of the next oldest fossil man—the Neanderthal or Mousterian type—the most striking difference in the brain-case is the presence in this later man of strong, bony brow-ridges like those of existing apes. It will also be noticed that the brain-case is much larger and the jaws are now human, though the face remains relatively well-developed. The differences in the brain-case between the earlier Piltdown and the later Neanderthal skulls thus correspond with those observable between the skull of a very young modern ape and that of the full-grown individual of the same species. The brow-ridges are, in fact, bony excrescences acquired during life. Now, on the principle of parallelism I have just mentioned, the ancestral Middle Tertiary apes (which we have not yet found) may be supposed to have had gently-rounded ovoid skulls without brow-ridges. In that case the Piltdown skull is much nearer in shape to that of its ancestor than the later Neanderthal skull. Hence, the Neanderthal race must be regarded as a degenerate offshoot of early man which has become extinct, and Piltdown man, or some close relative, may be on the direct line of descent of ourselves.

We see, therefore, from the study of the links in the chain of life found among extinct animals, that man, so far as his physical structure is concerned, is the natural outcome of the course of evolution we observe. It was not until the last phase in the geological history of the backboned animals that efficiency of the brain became of any real importance. The reptiles for long ages occupied every sphere of life and grew to astonishing proportions with only the most insignificant nervous centres. As soon as the warm-blooded mammals appeared, increase of brain-power became the essential factor in success in the struggle for existence. In most cases it merely kept pace with other changes in the body and aided in the general efficiency. In some cases where these animals of the highest grade continued to live in the forest (which we have every reason to believe was the original home of all), the development of the brain was the only real change that occurred in their structure. In one forest-dwelling race the momentum of this development resulted in such over growth that the brain eventually dominated the body, and the inevitable outcome was the primitive human frame.

APPENDIX.

The Formation of 'Rostro-carinate' Flints.
By Professor W. J. SOLLAS, *F.R.S.*

[Ordered by the General Committee to be printed *in extenso.*]

THE so-called 'rostro-carinate' flints discovered by Mr. Reid Moir at the base of the Red Crag and described by him [1] and Sir E. Ray Lankester [2] are known to have passed through an eventful history since they were first liberated from the parent chalk. They were exposed to the influence of the weather, possibly to torrent action, almost certainly to the impact of sea waves and as well, perhaps, to the pounding of coast ice on a beach. It would therefore seem reasonable to inquire whether they may not owe their peculiar forms to one or other of these natural agents.

If we examine the flints of a shingle beach such as that which fringes the foot of the cliffs in Alum Bay, Isle of Wight, we shall find many which present a rude resemblance to 'rostro-carinates,' but differing too much in detail to be of great value as evidence. This is only what we might expect, since the momentum of a wave falling on loose shingle is dissipated for the greater part in producing a general movement of the material. How difficult it is to break a stone lying on loose pebbles is well known to every geologist who has made the experiment with a hammer. The case is altered, however, when we pass, as at Selsey Bill, to thinly scattered flints lying on a sheet of firm clay. Here the blow of one stone driven upon another by the force of an advancing wave is capable of producing fractures on a larger scale. It was a consideration of this case that led me to visit Selsey, and I now propose to give a short account of the facts which fell under my observation at that place; but before doing so I should like to express my thanks to Mr. Heron-Allen, who guided me over the ground, and not only afforded me full access to his remarkable collection of flints from the foreshore of Selsey Bill, but gave me permission to help myself to any of the specimens which might prove of interest in this question. Mr. Heron-Allen has discovered many rostro-carinate forms among the Selsey flints, and one of them has been described by Sir E. Ray Lankester.[3]

The flints in question are exposed at Selsey Bill just above the mean level of the tide: they occur in scattered patches rather thinly strewn

[1] J. Reid Moir, 'The Flint Implements of Sub Crag Man,' *Proc. Prehistoric Soc. of East Anglia*, 1911, vol. 1, p. 17.

[2] E. Ray Lankester, 'On the Discovery of a Novel Type of Flint Implements,' *Phil. Trans. Roy. Soc.*, B, vol. 202, p. 283.

[3] *Loc. cit.* p. 332.

over the surface of the Bracklesham Clay, and closely associated with them are the well-known erratics of the southern drift. The former action of floating ice on these erratics, which has driven them forcibly into the underlying clay and sometimes crushed them to fragments, has been pointed out by Mr. Clement Reid.[4] Flints and erratics form together the base of the Pleistocene series as it exists at Selsey, and their exposure by the removal of this series under marine erosion is of very recent date.

All the flints of these patches present one or more fractured surfaces and some of them bear glacial striæ; the fractures, as shown by their patination, are of very different ages, but there is nothing to show that they have been produced by actions of more than one category. The deposit does not suggest a palæolithic or eolithic floor; it has all the characters of a geological formation.

The rostro-carinate form is very simple and may be produced by chance blows. It arises whenever an elongated mass of flint—a nodule or a fragment already blocked out by joints—is traversed by two surfaces of fracture which are inclined in opposite directions and converge so as to intersect along a line (carina).

Fragments fulfilling one or other or all of these conditions are to be met with on the Selsey beach, and they present a variety which is suggestive of chance rather than design. When the rostro-carinate form is attained it sometimes exhibits a 'ventral' flaking, but this, as in the examples from the Red Crag, is an inconstant character.

Among the most interesting flints at Selsey are some large irregular nodules with elongated rounded processes running out from them. These processes have been battered by the waves and have yielded in the same way as the simple nodules which have been converted into the rostro-carinate form. They are broken along surfaces which sometimes do and sometimes do not intersect; when they do a rostro-carinate form is produced, and this projects from the side of the ill-shaped nodule in a manner as difficult to associate with design as it is easy to interpret by the action of known natural causes.

From these nodules it is but a step to the 'paramoudras' of the Norfolk coast, which present similar processes similarly battered, but attain such dimensions that no single man unaided could lift one from its bed.

The flaking of the Selsey 'rostro-carinates' is as interesting as their form. Some are bounded by flaked surfaces having all the same kind of patination and therefore produced during one and the same geological epoch, but there are others in which these surfaces are distinguished by widely differing patinas, so that their existing form is the result of blows struck at widely separated periods, some during the Pleistocene and some during the recent epoch. The Abbé Breuil considers that some of the facets on the sub-Crag examples have been produced at different times.

Some of the most ancient of the uniformly patinated examples show

[4] Clement Reid, 'The Pleistocene Deposits of the Sussex Coast,' *Quart. Journ. Geol. Soc.*, 1892, vol. xlviii., pp. 344-64, in particular p. 350.

by the characters of their edges and their lateral facets that they were battered by chance blows.

It may be pointed out that the force of the waves is exerted in one general direction—*i.e.*, from sea to shore—and consequently that a nodule embedded in a clay beach may be expected to bear signs of directed blows. An excellent illustration of this is afforded by a nodule which I observed firmly seated in the Bracklesham Clay of Selsey beach. Its pyramidal extremity projected vertically upwards into the air, the ' ventral ' side was turned seawards, the two others towards the land, and the ventral edges exposed to blows from the sea were ' unilaterally ' flaked, the long axes of the flakes running perpendicularly to the edge. So far as the evidence afforded by the Selsey flints is clear it is uniformly suggestive of the action of natural causes and affords little support for explanations based on the intervention of man; it is thus consistent with the evidence drawn from other sources,[5] such, for example, as the wide geological range of the ' rostro-carinate ' form (from Upper Miocene to Pleistocene or even recent) and its apparent purposelessness, for it belongs to the same class of so-called implements as the eolithic scrapers which will not scrape, the borers which will not bore, and the planes which will not plane.

[5] See also F. N. Haward, 'The Chipping of Flints by Natural Agencies,' *Proc. Prehistoric Soc. of East Anglia*, 1912, vol. 1, p. 185; W. H. Sutcliffe, 'A Criticism of some Modern Tendencies in Prehistoric Anthropology,' *Mem. and Proc. Manchester Lit. and Phil. Soc.*, 1913, vol. 57, No. 7.

On the Phylogeny of the Carapace, and on the Affinities of the Leathery Turtle, Dermochelys coriacea. *By* Dr. J. VERSLUYS, *Assistant Professor of Zoology (Zoological Institute of the University of Giessen).*

[Ordered by the General Committee to be printed *in extenso.*]

THE Leathery Turtle or Leatherback, *Dermochelys coriacea*, is of special interest, as its shell is absolutely different from that of all other living turtles and tortoises. It is either the representative of a

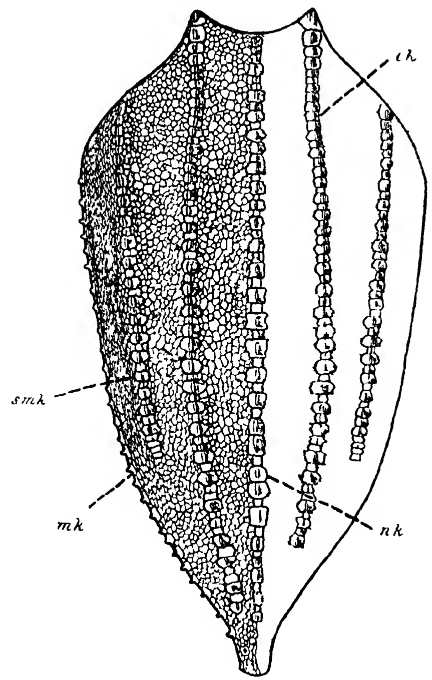

Fig. 1. Carapace of *Dermochelys*, dorsal view ; about $\frac{1}{13}$ natural size. The mosaic of small plates and the marginal keel are indicated on the left half of the carapace only.

ck, costal keel ; *mk*, marginal keel ; *nk*, neural keel ; *smk*, supramarginal keel.

very primitive offshoot of the Testudinate stem, or its shell represents a very remarkable modification of the common type.

The normal *Testudinata* possess a carapace formed by a relatively small number of bony plates: the costals, the neurals, the marginals, a nuchal, and often one or two suprapygals; the neurals and costals

are solidly united to the vertebræ and the ribs. In the Leatherback the carapace (fig. 1) is composed of a very large number of small, thin bony plates, fitting together with their jagged edges, forming a mosaic; and this carapace is separated from the vertebræ and the ribs by a very strong layer of connective tissue, the much thickened cutis. Of the whole normal carapace we recognise only one element in *Dermochelys*, the nuchal; it is separated from the overlying mosaic shell by the cutis.

The ventral side of the trunk is covered in typical *Testudinata* by an armour of bony plates, mostly nine, of the same type as the plates of the carapace, and forming the plastron. These elements are very old, having developed from the membrane bones of the shoulder-girdle and from the abdominal ribs (*Gastralia*), perhaps strengthened by a layer of dermal bone.[1] On the ventral side of the trunk of the Leatherback we find a very thick cutis, and imbedded on its inner side the elements of the normal plastron reduced to slender bars of bone. In *Psephophorus*, an extinct tertiary ally of the Leatherback, we find a complete ventral armour of small dermal ossicles at the sides of the animal, continuous with the dorsal mosaic of the carapace. This ventral armour is represented in the Leatherback by a small number of irregular ossicles lying in a median (partly paired) and two paired very incomplete lateral rows, five rows in all.[2] This remarkable difference in the dermal skeleton of *Dermochelys* and a few fossil allies on one side, and all the other turtles and the tortoises on the other, is the more curious, as the shell of the latter shows, on the whole, very little variation, the plates being fixed in number within very narrow limits, and eventual variation is mostly in the direction of reduction and gives us but little help in the interpretation of the aberrant shell of *Dermochelys*.

The problem of the phylogeny of the shell of *Dermochelys* would seem less puzzling if the Leatherback could be shown to represent a very primitive side-branch of the Testudinate-stem—viz. a suborder *Atheca*, all the other members of the order being united in the suborder *Thecophora*. This would allow the interpretation of the shell of *Dermochelys* as a primitive one, as a forerunner of the typical thecophorous shell.

This view, however, though adhered to by several competent authorities, seems untenable. It was refuted by Baur, Case, Dollo, van Bemmelen, and Wieland, who brought evidence that the *Atheca* are Cryptodirous *Testudinata*, rather closely related to the other marine turtles, and cannot represent a primitive offshoot, a primary division (sub-order) of the *Testudinata*. This conclusion is confirmed by Nick, Völker, and Menger, who have studied the Leatherback and the ontogeny of the shell in the *Testudinata* under the direction of Professor Spengel and myself in the Zoological Institute of the University of Giessen.[3] The mosaic shell of the *Atheca* must, then,

[1] *Cf.* Menger.

[2] Völker, 1913, pl. 30, fig. 2.

[3] This paper is largely a summary of the more extensive original papers by Nick (1912), Völker (1913), and Menger (not yet published); for all details I must refer to these papers. I am also greatly indebted to Professor Spengel for many useful suggestions.

be either a new formation or a modification of the thecophorous shell; it must have developed in a relatively short time, and the problem of its origin grows more puzzling and more interesting. We must first consider the evidence that the Leatherback belongs to the Cryptodirous *Testudinata* and is allied to the other marine turtles, *Chelonia* and *Thalassochelys* (*Cheloniidæ*), and related fossil forms (*e.g.* *Toxochelyidæ* and *Protostegidæ*). We must do so carefully, as the body of evidence considered convincing by Baur and others was judged insufficient by such competent authorities as Hay, Gadow (1901), and Boulenger.

It is well known that nearly all *Testudinata* can retract their head and neck within the shell, and that they do so in two different ways. In one group, the *Pleurodira*, the neck is bent sideways; in another, the *Cryptodira*, in a vertical plane, in a somewhat S-shaped curve. If we now compare the mode of articulation of the centra of the eight cervical vertebræ we find, somewhat masked by a number of aberrant cases, that there is a differentiation of these vertebræ into two groups, an anterior one with opisthocœlous, and a posterior with procœlous centra; the connecting vertebra is biconvex. In the *Cryptodira* it is typically thus:

1 (2 (3 (4) 5) 6) 7) 8)

It is obvious that this differentiation is an adaptation acquired in connection with the sharp bending of the neck when retracted; this is confirmed by its absence in those *Pleurodira*, which do not bend their neck in a double curve.

The typical marine turtles, the *Cheloniidæ*, also show this differentiation of the cervical vertebræ in two groups, and details prove that the cervical vertebral column is of the cryptodirous type. This cannot surprise us, as anatomy and palæontology prove that they are descendants from *Cryptodira*. The neck is shortened, and they can no longer retract their head. or even the neck, into the shell, but this is easily understood as a consequence of marine life.

The neck of the Leatherback is still shorter than in *Chelonia*,[4] and the centra of its vertebræ are united by thick cartilaginous pads, strengthened by strong fibrous tissue. Obviously the Leatherback cannot bend its neck in a strong curve. And yet we find the same differentiation of the cervical vertebræ into two groups as in the *Cryptodira* and in some *Pleurodira*. Certainly this complication cannot have been recently evolved in the Leatherback, with the obviously reduced articulations of its cervical centra; it can only be understood if we assume that these articulations were well developed in the ancestors of the Leatherback, and that these animals could bend their neck in a very strong curve. That this bending of the neck was performed in a vertical plane, as in the *Cryptodira*, and not sideways, as in the *Pleurodira*, is shown by the great resemblance in detail of the cervical vertebræ of the Leatherback with those of the *Cheloniidæ*, whilst no traces of the adaptations peculiar to the *Pleurodira* are found. We must conclude that the ancestors of the Leatherback could

[4] Völker, 1913, p. 493.

retract their neck in the same special way as the *Cryptodira* and belonged to this division of the *Testudinata.*

As the *Cryptodira* possess a typical thecophorous shell, inherited from the *Amphichelydia*, this shell must also have been present in the ancestors of the Leatherback. This conclusion is confirmed by the fact that parts of this shell, in a reduced state, are still found in the latter animal: the nuchal and the plastron. These elements represent a deeper layer of dermal ossifications, a thecal layer, whilst the mosaic shell represents a more superficial, epithecal [5] layer.

However astonishing in the light of the utterly different type of shell the assertion of Baur [5a] may seem, that *Dermochelys* is closely allied to the *Cheloniidæ*, the conclusion just reached, that the Leatherback belongs to the *Cryptodira*, like the *Cheloniidæ*, makes this view less improbable.

There certainly is in many respects a considerable resemblance in the skeleton of the Leatherback and the *Cheloniidæ*; but as both these types are modified in adaptation to marine life, a large amount of parallel modification and of convergence seems possible; the modification of the legs into paddles, a short, not retractile, neck, and a reduced plastron can certainly not be considered as proof of relationship. And, apart from the entirely different construction of the shell, there are other important differences, pointing rather to a more distant relationship—for instance, the strongly developed first rib and the absence of descending plates of the parietals to the pterygoids in *Dermochelys*,[6] and the different type of the sphenoid rostrum.[7] Yet the investigations of Baur, Nick, and Völker show several resemblances in structure, where convergence seems more or less improbable, and which cannot either be interpreted as very primitive characters, that might have been inherited independently from *Prochelonia.*

The most important points of common structure in *Dermochelys*, the *Cheloniidæ* and related turtles, are the following:

1. The cervical vertebral column is not only of the cryptodirous type, but it shows the same modification in two details. The articular surface uniting the centra of the sixth and seventh vertebræ is plane, and the strong spinous process of the eighth cervical forms a jointed articulation with the nuchal. Both these modifications lessen the flexibility of the hinder part of the neck, probably adaptations connected with the swimming life of marine turtles; but they are of such a special nature that it does not seem probable that this adaptation was acquired independently.

2. The pelvis shows a cartilaginous ischio-pubic bridge; the ischia are very small, the pubica large. The resemblance in the pelvis of *Dermochelys* and the common turtles is not very striking, and might be due simply to parallel adaptation connected with the use of the hind legs as paddles. There exists, however, a striking resemblance

[5] These layers are called subdermal and dermal respectively by Hay (1898; 1908, p. 17); as the deeper layer, however, is also formed in the cutis and is not subdermal in position, the terms thecal and epithecal are proposed (Völker, 1913, p. 475; especially Menger); compare Wieland, 1912, p. 299.

[5a] 1889 *a*, p. 180-191; 1889 *b*; 1890, p. 533.

[6] Boulenger, 1888.

[7] Versluys, 1909.

between the pelvis of the *Protostegidæ* and that of the Leatherback (fig. 2).[8]

3. There is only one central in the carpus.[9] The different arrange-

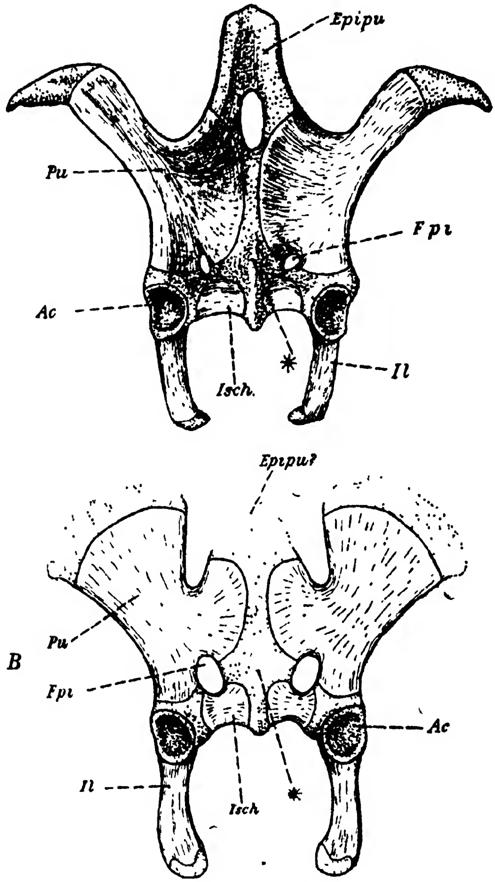

Fig. 2. *A*, Pelvis of *Dermochelys*, not yet fully adult, about $\frac{1}{8}$ nat. size (after Völker 1913, pl. 33, fig. 19), and *B*, Pelvis of *Archelon*, diagrammatic, about $\frac{1}{15}$ nat. size with the probable extent of cartilage in a young individual for comparison with fig. 2 *A* (based on figure of Wieland, 1900, p. 247, text fig. 6). Both ventral views, cartilage dotted.

Ac, acetabulum; *Epipu*, Epipubis; *F.p.i*, ischiopubic foramen; *Il*, ileum; *Isch*, ischium; *, cartilaginous symphysis.

ment and proportions of the carpals in the *Cheloniidæ* and *Dermochelys* make convergence improbable in this case.

4. The inner nares are bordered by the palatines and the vomer

[8] Compare Wieland, 1900, p. 246.

[9] Völker (1913, p. 460) found a rudiment of the second, radial, central in the young *Dermochelys*.

only, not by the maxillaries and intermaxillaries. This is easily understood in the *Cheloniidæ* and allied turtles (*Toxochelyidæ*) as the consequence of the formation of a secondary palate by the palatines (fig. 3, *B*). But in the Leatherback (fig. 3, *A*) there is no secondary palate, and the internal nares lie far forward in what seems to be a primitive position. The forward process of the palatines, that excludes the maxillaries and intermaxillaries from the border of the internal

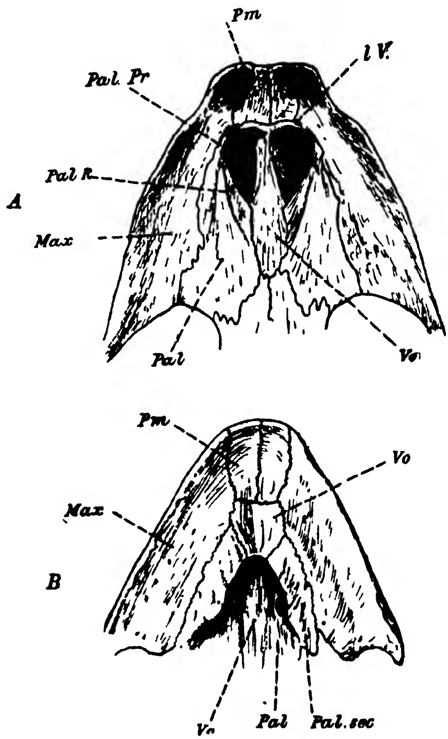

Fig. 3. *A*, Bones bordering the inner nares of *Dermochelys* and *B* of *Toxochelys procax* Hay. Fig. *A* about ¼ nat. size, after Nick, 1912, pl. 1, figs. 1 and 3; Fig. *B* about ⅔ nat. size, after Hay, 1908, p. 176, fig. 225.

l.V, lateral processes of the vomer in *Dermochelys*, excluding the premaxillaries from the border of the inner nares; *Max*, maxillaries; *Pal*, palatines; *Pal.Pr*, forward process of the palatines in *Dermochelys*; *Pal.R*, ridge on the palatines in *Dermochelys*, perhaps representing *Pal.sec*, the secondary palate formed by the palatines in *Toxochelys*; *Pm*, premaxillaries; *Vo*, vomer.

nares in *Dermochelys*, is also present (not reaching the vomer, however) in several primitive *Testudinata*, and Hay[10] denies on this ground its value as a token of relationship of the Leatherback with the *Cheloniidæ*. However, the process in the Leatherback is longer and reaches farther forward than in primitive *Testudinata*, is rather

[10] 1905, p. 157.

variable and very slender at the anterior end, often not quite reaching the vomer, and, to judge from its form and relations, seems to be undergoing a process of reduction.[11] From Hay's point of view, it remains quite obscure why the palatine should send such a slender process forwards in the Leatherback; the development of this process is best explained by Dollo's hypothesis,[12] that *Dermochelys* descends from a form with a secondary palate of the chelonoid type (for instance like *Toxochelys*).

5. The nasal cavities are built upon the same specialised type,[13] being divided by partition-walls into several independent chambers and showing several other minor details common to both forms. This is an important indication of relationship of *Dermochelys* and the *Cheloniidæ*, as the nasal cavity of the Leatherback is exceedingly short and its proportions are therefore quite different from those in the *Cheloniidæ*; these differences in proportions are best understood on the assumption that the nasal cavity was secondarily shortened in *Dermochelys*, and this points to a secondary forward movement of the internal nasal opening, as assumed by Dollo (here referred to under 4).

6. There is an intertrabecula in the skull of the ripe embryo.[14] The intertrabecula is a short median bar of cartilage, lying between the trabeculæ, reaching from the dorsum sellæ behind to the interorbital septum in front. It is not known in other *Testudinata*, and can only be interpreted as a special character of marine turtles, not as a primitive character inherited from the *Prochelonia*. That its presence in the *Cheloniidæ* and *Dermochelys* is the result of convergence is very improbable, as its later development in both forms is absolutely different, and there is no evidence for connecting it with marine life. Consequently the intertrabecula strongly favours near relationship of the Leatherback with other marine turtles.[15] Nick gives [16] numerous examples of other less important points of common structure in the skull of the Leatherback and *Chelonia*.

7. The œsophagus is covered with long, pointed, horncapped papillæ, directed towards the stomach.[17] Such papillæ are not known—at least not in the same completeness—in other *Testudinata*.[18]

Though one or other of these special resemblances may, in the light of more complete knowledge, lose its value as a proof of the relationship of *Dermochelys* with the *Cheloniidæ*, taken altogether they leave, to my mind, no other possibility than to accept a rather close relationship of these forms. Even the important differences in the shell, in the skull, &c. (compare p. 794), cannot make this conclusion invalid. But these differences are important, as they prove that *Dermochelys* is not a direct descendant of typical *Cheloniidæ*, as Baur

11 Nick, 1912, p. 62–65.

12 Dollo, 1903, p. 30; compare v. Bemmelen, 1896; Nick, 1912, p. 63.

13 Nick, 1912, p. 130–145 and p. 191–195.

14 Nick, 1912, p. 106–114.

15 Compare also Nick, 1912, p. 197.

16 p. 169.

17 Hoffmann, 1890, p. 243; Burne, 1905, p. 315.

18 According to Oppel, *Lehrbuch vergl. mikrosk. Anat. d. Wirbeltiere*, vol. 2, 1897, p. 82, Nuhn (*Lehrbuch vergl. Anat.*, Heidelberg, 1878) found dispersed pointed papillæ in some fresh-water tortoises.

once maintained, but that both types of marine turtles have evolved independently during a not inconsiderable time.[19] The common cryptodirous ancestor was probably a littoral form, as the special type of the cervical vertebral column and of the nasal cavities seems to be an adaptation to marine life acquired before the lines of development separated.[20]

Now, with this view of the phylogeny of *Dermochelys*, how are we to interprete the shell of this animal? How can we solve the problem that in one group of the *Testudinata*, in the marine turtles, the Leatherback and its few allies could acquire so aberrant a shell?

Dollo (1901) maintained that this shell is an entirely new formation, the old shell being nearly lost during life in the open sea, and then the new mosaic shell being developed under the influence of a temporary littoral life. This hypothesis concurs well with the relationship of *Dermochelys* with the *Cheloniidæ*. Völker (1913), however, has brought forward a somewhat different hypothesis,[21] that seems to have some advantage over that of Dollo. Völker sees in the shell of the Leatherback, not an entirely new formation, but the result of a secondary proliferation of old dermal ossifications present in its thecophorous ancestors, especially of the marginals. This view is based largely on facts and reflections published by Hay. Hay[22] contended that the primitive *Testudinata* possessed a double shell, the typical thecophorous shell having been covered by a more superficial layer of bones, forming seven longitudinal zones on the carapace and five on the plastron. The vast majority of turtles he assumed to have lost the superficial (epithecal) layer, *Dermochelys* only retaining it and losing nearly the entire thecophorous shell, the deeper or thecal layer.[23] To support this view Hay brought forward evidence that epithecal elements, representing the shell of the Leatherback, were present in primitive *Testudinata*. This last contention is confirmed by the investigations of Newman (1906), Wieland,[24] Völker, and Menger. The evidence may be summarised as follows:—

1. In *Toxochelys bauri*, a primitive marine turtle from the Upper Cretaceous, there are lying on the typical neurals in a discontinuous median series three (or four) small independent epithecal ossicles (fig. 4), called epineurals by Wieland[25]; epineurals were also present in other species of *Toxochelys*.[26] Corresponding epithecal elements have been found by Newman[27] under the keels of the second, third, fourth and fifth neural horny shields in the living tortoise *Graptemys geographica*, and less well developed in *Gr. pseudogeographica*, in exactly the same position as the epineurals of *Toxochelys*.

2. In *Archelon ischyros*, a marine turtle (fam. *Protostegidæ*) from

[19] Van Bemmelen, Case, Wieland, Nick, Völker.

[20] Compare Nick, p. 207–208, and Völker, p. 511; probably the ancestors of *Dermochelys* took early to life in the open sea, whilst those of the *Cheloniidæ* clung more to a littoral life.

[21] Compare also Nick, p. 209–211.

[22] 1898; 1905, p. 163; 1908, p. 17; compare also Wieland, 1912.

[23] Compare p. 794. [24] 1905, p. 332; 1909. [25] 1905, p. 325.

[26] Hay, 1908, p. 164; Case, 1898, p. 382. [27] 1906, p. 104.

the Upper Cretaceous, Wieland[28] found a complete series of eleven epineural elements (fig. 5, *Ep*) covering the much reduced real neurals and probably continuous in front over the nuchal. These elements correspond with the larger of bony scutes in the neural keel in the Leatherback (fig. 1).

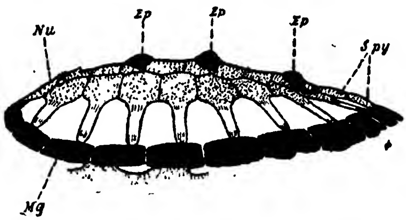

Fig. 4. Diagram of the Carapace of *Toxochelys bauri* Wieland, lateral view; about $\frac{1}{8}$ nat. size. After Wieland, 1905, p. 330, text fig. 3, from Menger. Epithecal elements black, thecal elements dotted.

Ep, epineurals; *Mg*, marginals; *Nu*, nuchal; *S.py*, suprapygals.

3. In *Archelon ischyros* again Wieland[29] discovered two more anomalous elements, obviously also epithecal. One element is free, the other united by its jagged edge with a typical marginal element, indicating the presence of a supramarginal row of epithecal elements (fig. 5, *Smg*); the jagged border of the marginals also points to the presence of such a series of elements.

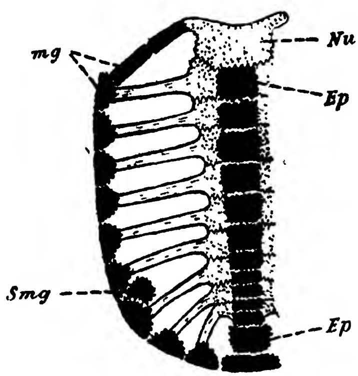

Fig. 5. Diagram of the Carapace of *Archelon ischyros* Wieland, dorsal view; about $\frac{1}{18}$ nat. size. After Wieland, 1909, p. 114, fig. 7, from Menger, somewhat modified. Epithecal elements black, thecal elements dotted.

Ep, epineurals; *mg*, marginals; *Nu*, nuchal; *Smg*, supramarginal.

4. The same turtle is obviously in the possession of typical marginal bony plates. Now, since these marginals are of the same character as the one supramarginal discovered in this animal, obviously lying in the same layer and possessing the same jagged edges (fig. 5,

[28] 1909, p. 115. [29] 1909, p. 120.

mg), it is highly probable that the marginals of the thecophorous shell are also epithecal.[30]

5. The same conclusion must be drawn from the discovery by Völker, that marginals may be recognised in the epithecal shell of *Dermochelys*. The lateral row of larger elements in that shell (fig. 1, *mk*) takes the same position in relation to the ends of the ribs as the typical marginals and, though more numerous, they are much like the marginals of *Archelon*. I find no valid reason why these elements in the Leatherback should not be true marginals, especially in the light of the relation of the marginals and supramarginals of *Archelon*.

If the marginals are epithecal elements, it is proven that such elements were present in the most primitive *Testudinata*.

6. In this connection it is of some importance that Menger found how, in the living tortoise *Emyda*, the marginals[31] develop in the middle layers of the cutis, whilst the 'thecal' elements (costal plates, neural plates, &c.) begin their development in the deepest layers of

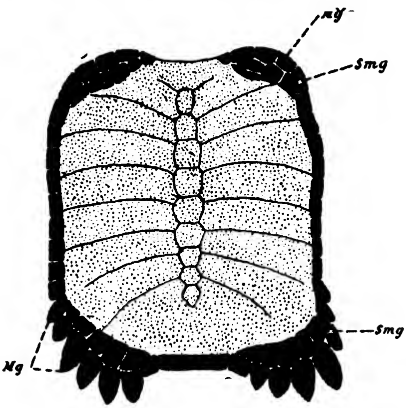

Fig. 6. Carapace of *Proganochelys Quenstedtii* Baur, dorsal view, diagrammatic; about $\frac{1}{10}$ nat. size. After Fraas, 1899, p. 409, text fig. 1, from Menger (1914). Epithecal elements black; thecal elements dotted.

Mg, marginals; *Smg*, supramarginals.

the cutis and only gradually reach the more superficial ones. In *Chelonia* and *Chelodina* the position of the developing marginals in the cutis was found to be less clear, although they certainly do not begin in the innermost layers of the cutis as do the thecal elements. This concurs with our conclusion that the marginals belong to another more superficial layer of dermal ossifications than the costal plates and the other thecal elements.[32]

[30] Völker, 1913, p. 521; Hay, however, assumed that the marginals belong to the thecal layer.

[31] I see no reason to doubt that these elements of *Emyda* are true marginals, though there is a possibility that they are secondary; compare Boulenger, 1889, p. 237–238.

[32] That the marginals differ from the rest of the shell was already pointed out by Goette (1899, p. 431–432) and Jaekel (1906, p. 62–67; 1914). Goette (and 1914 also Jaekel) sees in the marginal elements homologues with the mosaic-shell of *Dermochelys*.

7. In the primitive upper Triassic tortoise *Proganochelys* there was present a series of supramarginal bony plates (fig. 6), discontinuous in the middle but well developed anteriorly and posteriorly.[33] In the very interesting Upper Triassic form *Stegochelys*, Jaekel (1914) found a continuous series of eleven supramarginals on each side of the shell. If we compare these forms with the Leatherback and *Archelon*, it becomes probable that these elements also belong to the epithecal layer.

8. It is well known that the horny scales of reptiles often correspond with bony scutes. Hay and Newman, believing that horny scales develop in reptiles over bony scutes only,[34] concluded that the well-known horny shields of the *Testudinata* must also originally have developed upon the surface of bony scutes. As the shields are arranged differently from the bony plates of the thecophorous shell, they must have developed upon other ossifications, which can only have been 'epithecal.' Of course, we need not assume that these epithecal bony plates were as large as the horny shields are now, as the latter may have enlarged far beyond the border of the corresponding bony scutes. It is true that the bony marginals in *Testudinata*, though here supposed to belong to the epithecal layer, do not correspond to the marginal horny shields, but break joints with them.[35] Yet there seems to be some connection—*e.g.*, in case of abnormalities of the marginals the marginal horny shields always are abnormal too, and the reverse is also always true, whilst no such relation is found between the thecal elements and the overlying shields.[36] It is probable that in the very primitive *Proganochelys* and *Stegochelys* the bony marginals and supramarginals corresponded exactly with the overlying horny shields.[37] We cannot directly control the correspondence of bony and horny scutes in the Leatherback, as it has lost its shields in the adult and has not yet formed the osseous mosaic shell in the new-born specimens, whilst the intermediate ages are unknown; however, the young *Dermochelys*, as it leaves the egg, is covered with very small numerous horny shields, showing the same arrangement, with the typical rows of larger elements on the keels, as is found in the bony epithecal scutes of the adult.

The supramarginal horny shields of *Macroclemmys*, and of the extinct *Boremys* (*Amphichelydia*) are in this light also an indication of the former presence of bony supramarginals; and the inframarginal horny shields that are so widely distributed in the *Testudinata* point to the former development of an inframarginal series of bony elements.

The interpretation of Völker and Menger is in this important matter identical with the older view of Goette. But it differs essentially in that the costal and neural plates are considered parts of the inner skeleton by both Goette and Jaekel, whilst Menger has found what seems to me conclusive evidence, that they also are dermal ossifications, belonging to the same deeper layer as the nuchal and suprapygals. Compare Gegenbaur, 1898, p. 175-176.

[33] Jaekel, 1906, p. 66, who calls these elements submarginalia.

[34] This does not seem to be a hard and fast rule, as there is important evidence of the formation of horny scales independent of dermal ossifications in *Lacertilia* (Schmidt, 1910, p. 640; 1912, p. 86).

[35] This difficulty did not present itself to Hay and Newman, as they considered the marginals as belonging to the thecal layer.

[36] Newman, 1906, p. 96.

[37] Jaekel, 1906, p. 66; 1914.

Summarising, we find that there is a considerable amount of evidence pointing to the presence in primitive *Testudinata* of epithecal elements, lying on the thecal shell and completing it on the sides of the trunk. These elements were obviously arranged in a number of

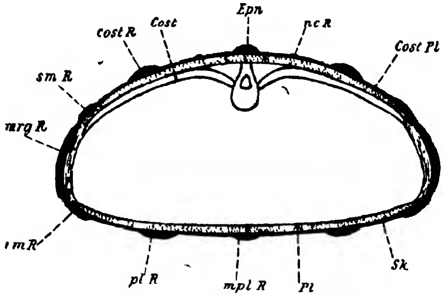

Fig. 7. *Diagrammatic transverse section through the shell of a hypothetical Prochelonian.* Elements of thecal layer dotted, of epithecal layer black.

Cost, costæ; *cost.Pl*, costal bony plates; *cost.R*, costal row of epithecal elements; *Epn*, epineurals; *im.R*, inframarginal row; *mpl.R*, median plastral row; *mrg.R*, marginal row; *nc.R*, neurocostal row; *Pl*, plastron; *pl.R*, plastral row; *sm.R*, supramarginal row; *Sk*, outer layers of skin.

longitudinal rows (fig. 7). In *Dermochelys* there are seven dorsal and five ventral rows of larger dermal ossifications, the dorsal ones being part of the mosaic shell and forming longitudinal keels on the back

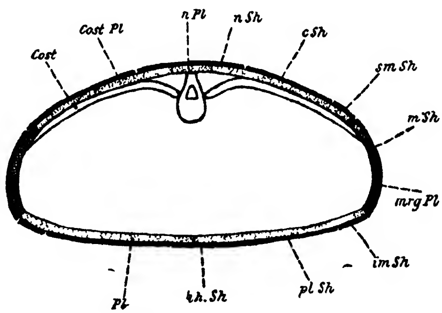

Fig. 8. *Diagrammatic transverse section through the shell of a normal thecophorous tortoise.* Elements of thecal layer dotted, of epithecal layer (the marginals) shaded; horny shields (probable representatives of epithecal elements of fig. 7) black.

Cost, costæ; *cost.Pl*, costal bony plate; *c.Sh*, costal horny shield; *ih.Sh*, interhumeral shield (representing the median plastral row in fig. 7); *im.Sh*, inframarginal shield; *mrg.Pl*, marginal bony plate; *m.Sh*, marginal horny shield; *n.Pl*, neural plate; *n.Sh*, neural shield; *Pl*, plastral bony plate; *pl.Sh*, plastral shield; *sm.Sh*, supramarginal shield.

(fig. 1). We have evidence of corresponding rows of epithecal elements in the thecophorous *Testudinata* (compare fig. 1 with figs. 7 and 8), the median dorsal row being represented by the epineurals and neural

shields, the lateral row by the marginals and marginal shields, the supramarginal row being present in *Archelon*, *Proganochelys*, and *Stegochelys*, and indicated by the supramarginal shields of *Macroclemmys* and *Boremys*. There is no direct evidence of a costal row corresponding to the costal keel of the Leatherback, but the costal shields may be taken as evidence of its former presence. On the plastron the median row of *Dermochelys* may be represented by the intergular and interhumeral shields present in some forms; the two paired rows of plastral ossifications in *Dermochelys*, probably developed as rows of larger horny scales in the young, may be represented by the plastral and inframarginal rows of shields in the *Theocophora*.

In this connection it is important that the keels of the shell of the Leatherback are found also in other *Testudinata*, being rather common in very young specimens. We can recognise them on the tail trunk of the snapping turtle, *Chelydra*, as rows of horny scales, partly combined with small dermal ossifications; there is one keel more here than in the Leatherback, a neurocostal keel lying between the neural- and costal-keels, but this row seems to be present also on the neck of the young *Dermochelys* as a row of larger yellow horny scutes like the rows that represent the other keels.[38] Though the keels in the *adult Dermochelys* appear to be rather an adaptation to the swimming habit of the animal, they yet are obviously connected with the keels in other *Testudinata*, and cannot well be interpreted as an entirely new acquisition, developed after the primitive thecophorous shell and horny shields had disappeared.

We conclude that Hay's hypothesis of the presence of superficial dermal ossifications, arranged in longitudinal rows in the *Prochelonicæ*, is supported by important evidence. However, we must take into account that, on the whole, traces of these epithecal elements, if we except the marginals, are very rare in fossil forms, even in the older ones, and this makes it improbable that these elements were strongly developed, forming continuous zones in the primitive *Testudinata*. There can only have been present small ossifications, loosely attached to the underlying thecal elements of the real shell. It seems possible that even the epineurals of *Toxochelys*, *Graptemys*, and *Archelon* are not really primitive epithecal elements, but newly formed ones; their very isolated appearance seems to point rather in this direction.

I am, on the base of this evidence, inclined to assume that in the immediate ancestors of the *Testudinata*, in the *Prochelonia*, there was present a *thecal* shell, composed of neurals, costals, the nuchal and suprapygals[39] dorsally and the plastron ventrally, and rows of *epithecal* dermal ossifications, covered with corresponding horny scutes, beginning on the neck and continued over the thecal shell and the tail (fig. 9). These epithecal elements were, however, only feebly developed and loosely attached to the thecal shell, with the exception of one row (perhaps two or three rows) on each side of the trunk,

[38] Compare Newman, 1906, p. 103, and Völker, 1913, p. 527.

[39] Compare Menger, whose paper brings a discussion of the nature of the nuchal and the suprapygals; and Gadow, 1899, p. 219.

where the thecal shell was incomplete (compare fig. 9). This lateral row soon reached a strong development, connecting the costals with the plastron, and thus completing the thecal shell by a row of epithecal elements, the marginals.[40] The other epithecal elements disappeared in the living thecophorous *Testudinata* (perhaps a few have been retained in *Graptemys*). In the ancestors of the Leatherback, how-

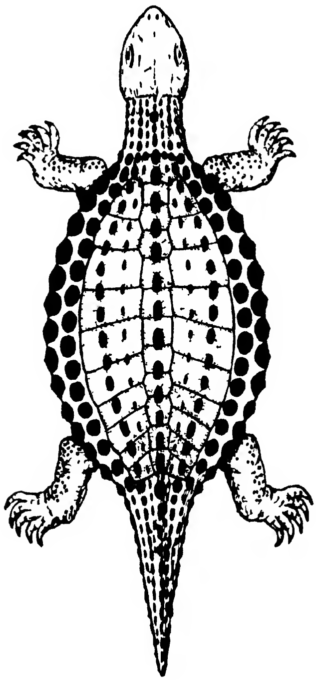

Fig. 9. *Hypothetical Prochelonian, dorsal view, to show the primitive state of the testudinate shell.* Thecal ossifications are dotted, epithecal elements black; only the larger epithecal ossifications have been indicated; between them were probably present numerous very small, irregularly distributed epithecal elements, perhaps represented by horny scutes only; the lateral epithecal ossifications (of the marginal and supramarginal row) are strongly developed, as they cover the space between the dorsal thecal ossifications and the plastron. For the identification of the rows of epithecal elements compare fig. 8; the rows are represented as continuous on the neck (as in the just born *Dermochelys*) and on the tail (as in *Chelydra*).

ever, these epithecal elements, instead of being more and more reduced, formed a new epithecal shell. We may assume that these ancestors reducing their heavy thecal shell and horny scutes in adaptation to a swimming life in the open sea, at the same time in some

[40] Sometimes the marginals are less firmly united with the costals, as these with the neurals. The same interpretation of the marginals is brought forward by Jaekel (1914).

respects replaced them by the new mosaic shell, formed by a proliferation of the marginals and such other epithecal elements as were present[41]: epineurals and probably elements in the other keels too. It must for the present be left undecided whether these 'other epithecal elements' were really primitive, connected without interruption with the epithecal elements of the *Prochelonia*, or whether these elements had been newly acquired, had reappeared, in the immediate, thecophorous, ancestors of the *Atheca* (in connection with a strong development of keels in the adult), showing the primitive arrangement that was prescribed by the position of the horny shields in these *Thecophora*. The new mosaic shell has obviously the advantage of being lighter, more elastic, and more superficial, thus protecting the *surface* of the thick cutis; it seems that a reduced thecal shell could not do this, as it would be limited to the deepest layers of the cutis, where it first forms in the embryo, and so, with its reduction the skin would have been insufficiently protected, especially if the horny scutes had been lost very soon too.

Archelon seems to have already acquired a complete epithecal shell, like *Dermochelys*,[42] but it certainly is much more primitive in several respects: neural and costal plates have not yet disappeared, the marginals are like those of other turtles, and the plastron is much less reduced. *Archelon*, with its largely completed mosaic shell, is an interesting intermediate form, connecting the mosaic shell of the Leatherback with the thecophorous shell of other turtles. How far the shell of the Leatherback is directly connected with that of *Archelon* is difficult to decide, but *Archelon* shows at least that a transformation of the shell as here assumed for *Dermochelys* was possible, as it was largely completed in *Archelon*.

It need not be emphasised that the phylogeny of the shell of the Leatherback here assumed is hypothetical, and that only new discoveries and investigations can show whether it or Dollo's view, that the shell of *Dermochelys* is quite unconnected with the thecophorous shell of its ancestors, comes nearest the truth. But I may be permitted to point out what seem to me the advantages of the new hypothesis over that of Dollo: (1) The view that the marginals take part in the formation of the new shell concurs with what is shown by *Archelon*, where they do form part of the mosaic shell. (2) The presence of keels in *Dermochelys* corresponding to the keels in *Thecophora* points to a connection existing between the shells of both types. (3) The formation of the new shell by a proliferation of elements already present in the thecophorous ancestors seems a less complicated process than an entirely new formation. We conclude that:

(*a*) The shell of tortoises and turtles is formed by a combination of two layers of dermal ossifications, a thecal layer and a more superficial epithecal layer, the latter generally represented by the marginals only.

[41] Jaekel (1914) gives an interpretation of the shell of *Dermochelys* that has much in common with the views of Völker and Menger.

[42] Wieland, 1909, p. 120.

(*b*) The Leatherback is a member of the *Cryptodira*, and allied to the other marine turtles.

(*c*) The problem of the origin of the aberrant shell of the Leatherback seems to find its solution in the hypothesis that it is a secondary proliferation of the marginals and such other 'epithecal' elements as were present in its thecophorous ancestors.

LITERATURE.

Baur, G. (1889 *a*). Die systematische Stellung von *Dermochelys* Blainv. in 'Anat. Anzeiger,' vol. 9 (1889–90), p. 149–153, 180–191.

—— (1889 *b*). Nachträgliche Bemerkungen über die systematische Stellung von *Dermochelys* Blainv., in 'Biol. Centralblatt,' vol. 9 (1889–1890), p. 618–619.

—— (1890). On the classification of the *Testudinata*, in 'American Naturalist,' vol. 24, p. 530–536.

Van Bemmelen, J. F. (1896). Bemerkungen über den Schädelbau von *Dermochelys coriacea*, in 'Festschrift Gegenbaur,' vol. 2, Leipzig, 1896, p. 279–286.

Boulenger, G. A. (1888). Remarks on a note by Dr. G. Baur on the Pleurodiran Chelonians, in 'Ann. Mag. Nat. Hist.' (6), vol. 2, p. 352–354.

—— (1889), Catalogue of the Chelonians, Rhynchocephalians and Crocodiles in the British Museum, London.

Burne, R. H. (1905), Notes on the muscular and visceral anatomy of the Leathery Turtle (*Dermochelys coriacea*), in 'Proc. Zool. Soc.,' London, p. 291–324.

Case, E. C. (1897). On the osteology and relationships of *Protostega*, in 'Journ. Morphol.,' vol. 14, 1898, p. 21–58.

—— (1898), *Toxochelys*, in 'University Geol. Survey of Kansas,' vol. 4, Palæont., Part I., p. 370–385.

Dollo, L. (1901). Sur l'origine de la Tortue Luth (*Dermochelys coriacea*), in 'Bull. Soc. Sc. méd. nat.,' Bruxelles, p. 1–26.

—— (1903). *Eochelone brabantica*, Tortue marine nouvelle du Bruxellien (Eocène moyen) de la Belgique (Sur l'évolution des Chéloniens marins), in 'Bulletin Acad. Belg.,' 1903, No. 8, p. 792–850.

Fraas, E. (1899). *Proganochelys Quenstedtii* Baur (*Psammochelys Keuperiana* Qu.), in 'Jahreshefte Ver. vaterl. Naturk.,' Württemberg, 1899, p. 401.

—— (1913). *Proterochersis*, eine Pleurodire Schildkröte aus dem Keuper, ibid., 1913, p. 13–30.

Gadow, H. (1899). Orthogenetic Variation in the Shells of Chelonia, in 'Willey's Zoological Results,' p. 207–222.

—— (1901). Amphibia and Reptiles; Cambridge Natural History, vol. 8. London.

Gegenbaur, C. (1898). Vergl. Anatomie d. Wirbelthiere, vol. 1. Leipzig.

Hay, O. P. (1898). On *Protostega*, the systematic position of *Dermochelys*, and the morphogeny of the Chelonian carapace and plastron, in 'Amer. Natural.,' vol. 32, p. 929–948.

—— (1905). On the Group of Fossil Turtles, known as the *Amphichelydia*, in 'Bull. Amer. Mus. Nat. Hist.,' vol. 21, p. 137–175.

—— (1908). The Fossil Turtles of North America (Carnegie Institute, Public. No. 75), Washington.

Hoffmann, C. K. (1890). Schildkröten, in Bronn's 'Klassen und Ordnungen Thierreich.,' vol. 6, Abt. 3, 1.

Jaekel, O. (1906). *Placochelys placodonta* aus der Obertrias des Bakony, in 'Result. wiss. Erforschung Balatonsee,' vol. 1, Teil 1, paläont. Anhang, p. 1–91.

—— (1914). *Stegochelys*, in 'Palaeontologische Zeitschrift,' Organ der Palaeont. Gesellsch., herausgegeb. von Jaekel, vol. 1.

Menger, W. (1914). Ueber die Ontogenie des Schildkrötenpanzers, in 'Zoolog. Jahrb., Anat.' (not yet in print).

Newman, H. H. (1906). The significance of scute and plate abnormalities in *Chelonia*, in 'Biolog. Bull.,' vol. 10, p. 69–114.

Nick, L. (1912). Das Kopfskelet von *Dermochelys coriacea* L., in 'Zool. Jahrb.,' vol. 33, Anat., p. 1–238.

Schmidt, W. J. (1910). Das Integument von *Voeltzkowia mira* Bttgr., in 'Z. wiss. Zool.,' vol. 94, p. 605–720.

Schmidt, W. J. (1912). Studien am Integument der Reptilien, III. Die Haut der Gerrhosauriden, in ' Zool. Jahrb.,' vol. 35, Anat., p. 75–104.
Versluys, J. (1909). Ein grosses Parasphenoid bei *Dermochelys coriacea* Linn., in ' Zool. Jahrb.,' vol. 28, Anat., p. 279–294.
Völker, H. (1913). Ueber das Stamm-, Gliedmassen- und Hautskelet von *Dermochelys coriacea* L., in ' Zool. Jahrb.,' vol. 33, Anat., p. 431–552.
Wieland, G. R. (1900). The Skull, Pelvis, and probable relationships of the Huge Turtles of the genus *Archelon* from the Fort Pierre Cretaceous, in ' Amer. Journ. Sci.,' vol. 9 (ser. 4), p. 237–251.
—— (1905). On Marine Turtles, ibid. vol. 20 (ser. 4), p. 325–343.
—— (1909). Revision of the *Protostegidae*, ibid. vol. 27 (ser. 4), p. 101–130.
—— (1912). On the Dinosaur-Turtle Analogy, in 'Memorie Accad. Sci. Bologna, Cl. Sci. Fis., Sez. Sci. Nat.,' vol. 9 (ser. 6), p. 297–300. Published also in 'Science,' vol. 36, N. Ser., p. 287–288.

Liquid, Solid, and Gaseous Fuels for Power Production.
By Professor F. W. BURSTALL, *M.A.*

[Ordered by the General Committee to be printed *in extenso.*]

THE general problem of power production is one of the most fascinating subjects to all engineers, and the author proposes to consider some of the means in which carbonaceous substances may be treated to render them suitable for the production of power.

The fuel of the world consists of two forms, liquid and solid, both of which are closely related, inasmuch as they consist of compounds of carbon and hydrogen together with small percentages of other substances such as nitrogen.

To most engineers coal is looked upon purely from the point of view of a fuel to use in a furnace for the production of heat. It is, however, a complicated substance from which can be extracted a wide range of valuable products in addition to its value as a means for the production of heat.

It is often assumed that the oil-engine in one of many forms is likely to be the heat-engine of the future, and at first sight there is much to be said for this contention. For the heat-engine as a thermodynamic machine oil is immensely superior to either solid or gaseous fuels because of its high heating value and from the ease in which it can be introduced into the working fluid. Putting on one side steam for the present, the problem is to heat up a mass of air confined in a cylinder. It was soon found by Stirling and many others in the early part of the nineteenth century that it was extremely difficult to rapidly heat up a mass of air by conduction through a metal plate, the only feasible method being to mix the fuel with air and ignite inside the cylinder.

In order to ensure complete and rapid heating up of the air the mixture must be as intimate as possible, which is, of course, readily and simply obtained with a gaseous fuel, but there are points in the use of gaseous fuel which lead to serious difficulties. In order to secure efficiency the main mass of the air must be heated by compression before the principal heat supply is added; the combustible gas may be added before compression begins, as in the well-known Otto cycle; but this introduces a possibility of the charge igniting before the correct time: it also requires that the gas should be free from any liquid or solid substances, a state of affairs not easy to obtain on a large scale. If the gas be compressed in a separate pump there is a certain loss of heat due to necessary cooling of the pump. These inherent defects of the gas-engine will probably prevent it ever being made in sizes which approach the steam-turbine. With a liquid fuel there is no difficulty in forcing the small amount of oil

required into the pre-heated air, and the oil is readily freed from foreign matter; also there does not appear to be any inherent reason why the oil-engine should not be made in the largest sizes beyond those of weight and cost, where it must always be inferior to the rotary machine.

There remains now to consider the question of the gas-turbine. It can be readily shown that the velocities which have to be dealt with are no greater than those encountered in the steam-engine, and where then come the difficulties which, in spite of innumerable efforts, have so far proved insurmountable.

The greatest defect is that so far it has not been found feasible to compress the air and gas in the turbine itself. Separate compression considerably increases the losses, so that in place of the negative work being one-third of the gross work, it would probably be at least one-half, and perhaps more. The cooling of the rotating disc and blades offers difficulties, and also so far no material has been found that will withstand the erosive effect of the burning gases. It seems very doubtful if the gas-turbine can be constructed to compete with the reciprocator on the present state of knowledge.

It is important to consider the amount of various fuels which are raised in various parts of the world. At present about twelve hundred million tons of coal of various kinds are brought to the surface every year. Crude oil amounts to about fifty million tons per year, and it is doubtful if there are any large oilfields yet to discover; it therefore follows that the supply of oil is totally inadequate in amount to replace coal for power production on a scale equal to the present steam-power production.

The artificial production of oil is one that at present is being considered seriously by engineers, and there is very little doubt that much yet remains to be discovered in this field. Every engineer is familiar with the fact that when coal is heated in a closed retort gas and tar are given off, and also that the higher the temperature at which gasification takes place the greater is the yield of gas and less tar is formed. Tar when distilled gives a number of valuable substances, but only a small fraction of light oils; the middle oils contain some cresylic acid which is suitable for the Diesel motor.

Up to the present coal has been gasified with the object of making the highest yield of gas, but it is quite possible to alter the conditions of carbonisation so as to obtain a high yield of fuel oils and other compounds of value. As a side issue, but an important one, is the production of sulphate of ammonia, the use of which as a manure is steadily increasing in all countries of the world.

Sulphate of ammonia is the most valuable manure where nitrogen is needed, and the author considers it is one of the greatest defects of the crude burning of coal that such enormous amounts of nitrogen are not only wasted, but turned into nitric acid in the atmosphere. Of course the nitric acid is returned to the soil by the agency of rain, but not necessarily where required by the cultivator.

It will now be necessary to consider the methods by which fuels may be utilised for the production of power. Oil has been shown to

apply only partially; the steam generation of power is familiar to all, so the various forms of gas production need only be touched upon.

Gas power can be obtained in the following ways:

1. Town gas, made in closed retorts.
2. Producer gas, made by blowing air and steam into incandescent fuel.
3. Gas from coke ovens, where the production of hard coke is the primary end.

From one ton of coal gasified in a modern gasworks are obtained 11,500 to 12,506 cubic feet of gas having a calorific value of about 550 B.T.U. per cubic foot, about ten gallons of tar, and 25 to 30 lb. of sulphate of ammonia. The gas has to be purified for domestic purposes. Also a gasworks has to be near a great town, where the working expenses are not so low as in a more rural part. For these reasons it is doubtful if town gas can be supplied under present conditions for much under tenpence per thousand cubic feet.

A good gas-engine and dynamo will give one kilowatt hour for 20 cubic feet of gas—that is, at a fuel cost of 0.2*d.* per kilowatt hour, which, of course, is too high for large-sized units.

Despite these facts the author is of opinion, after mature consideration, that the whole problem of fuel treatment will lie in the direction of heating the coal, peat, or lignite in a closed retort—not of necessity under the conditions which are at present forced on to the gasworks, where the primary object is to produce the largest yield of gas on a certain standard laid down by Parliament.

If it be granted that the quantity, quality, and purity of the gas produced are a secondary matter, the problem of fuel treatment becomes one of the most fascinating problems which the engineer can encounter.

It has long been known that the quantity and quality of the tar are largely influenced by the temperature at which the fuel is carbonised: the lower the temperature the better are the tars in both yield and composition. The amount of sulphate of ammonia recovered from the gas is only some 25-30 lb. per ton of coal, whereas the amount of nitrogen present in the coal would give about 120 lb. of sulphate of ammonia. In the ordinary process of carbonisation some three-quarters of the nitrogen is left behind in the coke. Under present conditions this cannot be avoided, but improvements in this direction are possible.

If the gas and tars are withdrawn from the heat directly they are evolved from the coal a set of products will be obtained of a different composition from those usually found in gasworks tar. Many of these oils can, after distillation, be employed as fuel oils for power production, both the light oils, such as benzole, pentane and hexane, and middle oils, such as cresylic acid, while the heavy oils of the anthracene series appear to be of value for lubricating purposes.

The author trusts that an engineering audience will pardon him for outlining a scheme of fuel treatment which is at present wholly beyond the region of practical realisation. The first step is to obtain a coalfield of wide extent yielding a coking coal. It need not be within a short distance of towns, as that will merely modify the means of

transmission, the essential point being to obtain a sufficient supply of coal to enable the capital charges being repaid in a series of years, probably thirty.

The works would have to be on a large scale to enable the economy of working that always results from wholesale production, but the carbonisation plant would be placed near the pithead so that the tubs could discharge direct into the bunkers of the retort-charging machines. A convenient size for each plant would be about two thousand tons per day, and there would be some five to six pits operating over quite a large area. There would be no gain from any point of view in not shipping direct from the pithead the coke and sulphate of ammonia, as these would be ready for market without further treatment.

Tar and gas would be taken by pipe-lines to suitable points for their future treatment, depending upon geographical considerations. The tar from the whole of the works would be passed through continuous automatic stills, where the various fractions would be obtained with the least expense. The fractions, after washing with acid and soda, would pass to a second set of automatic stills, this process being continued until the pure products ready for market were obtained without the necessity for storage and in the least possible space of time.

As to how far the treatment of residuals should be carried no definite answer can be given, as it depends on the current prices, but on the scale considered—120,000 to 140,000 gallons of tar per day—it would certainly be advantageous to treat the products to a finish. That portion of the gas not required for firing the automatic stills and for colliery purposes generally would be led to a different point perhaps many miles from the pithead. This offers no difficulty as regards the power required, the great obstacle being the cost of the pipe-line. This may to a large extent be reduced by gasholders at the delivery end so as to improve the load factor on the pipe-line. The gas would be free from tar, but would contain the sulphur compounds, and would be employed in gas-engines for the generation of electricity, which would be sent at high voltages not only to the towns, but for the railways which are supposed to be entirely electrified.

No doubt electrical engineers will look askance at gas-engines, not only from the many failures that have occurred with large engines, but also at the fact that at present some 2,000 h.p. is the largest size that can be built, whereas a steam turbine can be constructed to give an output of 20,000 k.w. at a low first cost. The gas-engine can only compete with the steam-turbine when its fuel gas is delivered to it at a price which will, when helped by its high thermal efficiency, enable it to get over its large capital outlay. Perfect as is the steam-turbine as a mechanical machine, its thermal efficiency is half that of its rival; the cost of the steam delivered to it cannot be reduced, as the boiler has but a small margin of improvement possible. There are no by-products, as the whole of those contained in the coal are used to pollute the atmosphere.

For these reasons it is quite possible for the gas-engine to produce current more cheaply than the turbine. The price of gas of a calorific value of 500 B.T.U. per cubic foot would have to be about fourpence

per thousand cubic feet. If coal be taken as twenty shillings per ton, this will give for each fuel about 125,000 B.T.U. per penny. Taking the gas-engine as two and a half times as efficient as the turbine, this should leave enough margin to compensate for the increased capital outlay.

The exhaust gases would be washed so as to extract the sulphuric acid, which would be returned to the pithead for the manufacture of sulphate and the washing of the tars, so that all the external material to be purchased is the soda ash used to neutralise the excess acid. In this manner the whole of the products of the coal would be recovered in a form ready for the market, and if the coke were used as a domestic fuel a smoke-laden atmosphere would be impossible.

Producer-gas for power and heating purposes has a large field in front of it, particularly when the factory is widely distant from the coalfield, and also where there is steady load of large amount, such as electrolytic production.

In producer-gas the whole of the fuel is converted into gas and tar so that a large quantity of gas (120,000 to 140,000 cubic feet) can be obtained per ton of coal; the ammonia yield is very high, being from 80 to 90 lb. of sulphate per ton; the calorific value of the gas is low, about 140 B.T.U. per cubic foot; and the tar is small in quantity and poor in quality, as it is nearly all pitch.

The low calorific value and the difficulty of cleaning the gas are serious drawbacks to the transmission over long distances. In South Staffordshire producer-gas has been piped over a wide area for several years, and the undertaking now appears to be on sound financial ground. The suction producer working on coke or anthracite coal has a very definite position for small plants in remote districts, where it forms a cheap and reliable source of power.

The propulsion of ships by internal-combustion engines is one of the most important problems of the near future; the gas-engine itself offers no special difficulty, but to instal a producer plant of large size does not appear to the author to be possible for the following reasons: The space taken by the producers alone is large, and in addition there is the cleaning plant. Again, when the percentage of the poisonous carbon monoxide is high, 15 per cent. to 20 per cent., the plant should be entirely in the open air to prevent the risk of gassing. These conditions are most difficult to fulfil, and now that the Diesel motor has proved itself to be suitable for marine propulsion the more cumbersome and dangerous producer will be discarded.

Taking the question of producer-gas as a whole it would seem as if it will always have a definite use but only a limited application, more especially in a country like Great Britain, where in time it will be possible in almost every part to obtain electricity cheaply in bulk. When this is the case no other source of power need be considered.

The case of coke ovens really falls into the same class as the retorted gas, the only difference being that to obtain a coke capable of carrying the weight of the iron in the blast furnace the temperature of carbonisation must be high (1,200° C.) and the period long—twenty-four to thirty hours. Thus the tars are poorer from being more split up,

and the cost of repairs to the ovens considerably higher than on a gasworks retort.

As hard coke must be made, the place for it is in conjunction with the ordinary plant so that the by-products may be readily worked up.

The author wishes to point out to an audience which contains many electrical engineers that there is no real rivalry between gas and electricity when they are viewed from a broad standpoint. Both take their origin from coal, and each is capable of doing things that the other cannot. The work of the engineer is to consider them both and to see if he cannot, by marrying the two together, obtain from the coal more products useful to man than by shutting his eyes to merits in any subject outside his own studies and experiences.

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O. J. R. HOWARTH, M.A., Burlington House, London, W.

CHIEF CLERK AND ASSISTANT TREASURER.

H. C. STEWARDSON, Burlington House, London, W.

GENERAL ORGANISING SECRETARY FOR THE AUSTRALIAN MEETING.

A. C. D. RIVETT, B.A., D.Sc., University of Melbourne, Victoria.

ORDINARY MEMBERS OF THE COUNCIL.

ARMSTRONG, Professor H. E., F.R.S.
BRABROOK, Sir EDWARD, C.B.
BRAGG, Professor W. H., F.R.S.
CLERK, Dr. DUGALD, F.R.S.
CRAIGIE, Major P. G., C.B.
CROOKE, W., B.A.
DENDY, Professor A., F.R.S.
DIXEY, Dr. F. A., F.R.S.
DIXON, Professor H. B., F.R.S.
FARMER, Professor J. B., F.R.S.
GRIFFITHS, Principal E. H., F.R.S.
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HALL, A. D., F.R.S.
HALLIBURTON, Professor W. D., F.R.S.
IM THURN, Sir E. F., K.C.M.G.
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LYONS, Captain H. G., F.R.S.
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MYRES, Professor J. L., M.A.
PRAIN, Sir DAVID, C.I.E., F.R.S.
SHERRINGTON, Professor C. S., F.R.S.
TEALL, Dr. J. J. H., F.R.S.
THOMPSON, Dr. SILVANUS P., F.R.S.
TROUTON, Professor F. T., F.R.S.

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The Trustees, past Presidents of the Association, the President and Vice-Presidents for the year, the President and Vice-Presidents Elect, past and present General Treasurers and General Secretaries, past Assistant General Secretaries, and the Local Treasurers and Local Secretaries for the ensuing Annual Meeting.

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The Right Hon. Lord RAYLEIGH, O.M., M.A., D.C.L., LL.D., F.R.S., F.R.A.S.
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Sir W. Turner, K.C.B., F.R.S.
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Sir James Dewar, LL.D., F.R.S.
Sir Norman Lockyer, K.C.B., F.R.S.
Arthur J. Balfour, D.C.L., F.R.S.
Sir E. Ray Lankester, K.C.B., F.R.S.
Sir David Gill, K.C.B., F.R.S.
Sir Francis Darwin, F.R.S.
Sir J. J. Thomson, O.M., F.R.S.
Prof. T. G. Bonney, Sc.D., F.R.S.
Sir W. Ramsay, K.C.B., F.R.S.
Sir E. A. Schäfer, LL.D., F.R.S.

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A. Vernon Harcourt, D.C.L., F.R.S.
Sir A. W. Rücker, D.Sc., F.R.S.
Sir E. A. Schäfer, LL.D., F.R.S.
Dr. D. H. Scott, M.A., F.R.S.
Dr. G. Carey Foster, F.R.S.
Dr. J. G. Garson.
Major P. A. MacMahon, F.R.S.

AUDITORS.

Sir Edward Brabrook, C.B.
Professor H. McLeod, LL.D., F.R.S.

LIST OF MEMBERS

OF THE

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

1913.

* indicates Life Members entitled to the Annual Report.
§ indicates Annual Subscribers entitled to the Annual Report.
‡ indicates Subscribers not entitled to the Annual Report.
Names without any mark before them are Life Members, elected before 1845, not entitled to the Annual Report.
Names of Members of the GENERAL COMMITTEE are printed in SMALL CAPITALS.
Names of Members whose addresses are incomplete or not known are in *italics*.

Notice of changes of residence should be sent to the Assistant Secretary, Burlington House, London, W.

Year of Election.

1905. *à-Ababrelton, Robert, F.R.G.S., F.S.S. P.O. Box 322, Pietermaritzburg, Natal. Care of Royal Colonial Institute, Northumberland-avenue, W.C.
1887. *ABBE, Professor CLEVELAND. Local Office, U.S.A. Weather Bureau, Washington, U.S.A.
1881. *Abbott, R. T. G. Whitley House, Malton.
1885. *ABERDEEN, The Earl of, G.C.M.G., LL.D. Haddo House, Aberdeen.
1885. ‡Aberdeen, The Countess of. Haddo House, Aberdeen.
1873. *ABNEY, Captain Sir W. DE W., K.C.B., D.C.L., F.R.S., F.R.A.S. (Pres. A, 1889; Pres. L, 1903; Council, 1884–89, 1902–05, 1906–12.) Measham Hall, Leicestershire.
1905. §Aburrow, Charles. P.O. Box 534, Johannesburg.
1913. §Ackland, T. G., F.I.A. 5–6 Clement's Inn, Strand, W.C.
1869. ‡Acland, Sir C. T. Dyke, Bart., M.A. Killerton, Exeter.
1877. *Acland, Captain Francis E. Dyke, R.A. Walwood, Banstead, Surrey.
1894. *ACLAND, HENRY DYKE, F.G.S. Chy-an-Mor, Gyllyngvase, Falmouth.
1877. *Acland, Theodore Dyke, M.D. 19 Bryanston-square, W.

Year of Election.

1904. ‡Acton, T. A. 41 Regent-street, Wrexham.
1898. ‡Acworth, W. M., M.A. (Pres. F, 1908.) The Albany, W.
1901. ‡Adam, J. Miller. 15 Walmer-crescent, Glasgow.
1887. ‡Adami, J. G., M.A., M.D., F.R.S., Professor of Pathology in McGill University, Montreal, Canada.
1901. §Adams, John, M.A., B.Sc., LL.D. (Pres. L, 1912), Professor of Education in the University of London. 23 Tanza-road, Hampstead, N.W.
1904. ‡Adams, W. G. S., M.A. Department of Agriculture, Upper Merrion-street, Dublin.
1869. *Adams, William Grylls, M.A., D.Sc., F.R.S., F.G.S., F.C.P.S. (Pres. A, 1880; Council, 1878–85.) Heathfield, Broadstone, Dorset.
1908. *Adamson, R. Stephen. The University, Manchester.
1913. §Addison, W. H. F. Medical School, The University of Pennsylvania.
1890. ‡Adeney, W. E., D.Sc., F.C.S. Burnham, Monkstown, Co. Dublin.
1913. §Adeney, Rev. Professor W. F., M.A., D.D. Lancashire College, Whalley Range, Manchester.
1913. §Adeney, Mrs. Lancashire College, Whalley Range, Manchester.
1899. *Adie, R. H., M.A., B.Sc. 136 Huntingdon-road, Cambridge.
1908. §Adkin, Robert. 4 Lingard's-road, Lewisham, S.E.
1912. §Afanassieff, Apollo. Physical Institute, Imperial University, St. Petersburg.
1908. *Agar, W. E., M.A. Natural History Department, The University, Glasgow.
1902. ‡Agnew, Samuel, M.D. Bengal-place, Lurgan.
1906. §Aikman, J. A. 6 Glencairn-crescent, Edinburgh.
1871. *Ainsworth, John Stirling. Harecroft, Gosforth, Cumberland.
1909. *Aird, John. Canadian Bank of Commerce, Toronto, Canada.
1911. §Airey, John R., M.A., B.Sc. 73 Claremont-road, Forest Gate, E.
1895. *Airy, Hubert, M.D. Stoke House, Woodbridge, Suffolk.
1891. *Aisbitt, M. W. Mountstuart-square, Cardiff.
1871. §Aitken, John, LL.D., F.R.S., F.R.S.E. Ardenlea, Falkirk, N.B.
1901. ‡Aitken, Thomas, M.Inst.C.E. County Buildings, Cupar-Fife.
1884. *Alabaster, H. Milton, Grange-road, Sutton, Surrey.
1886. *Albright, G. S. Broomsberrow Place, Ledbury.
1905. ‡Albright, Miss. Finstal Farm, Finstal, Bromsgrove, Worcestershire.
1913. §Albright, W. A. 29 Frederick-road, Edgbaston, Birmingham.
1900. *Aldren, Francis J., M.A. The Lizans, Malvern Link.
1896. §Aldridge, J. G. W., Assoc.M.Inst.C.E. 39 Victoria-street, Westminster, S.W.
1905. *Alexander, J. Abercromby. 24 Lawn-crescent, Kew.
1888. *Alexander, Patrick Y. 3 Whitehall-court, S.W.
1910. *Alexander, W. B., B.A. Western Australian Museum, Perth, West Australia.
1891. *Alford, Charles J., F.G.S. Hotel Victoria, Rome.
1883. ‡Alger, W. H. The Manor House, Stoke Damerel, South Devon.
1883. ‡Alger, Mrs. W. H. The Manor House, Stoke Damerel, South Devon.
1901. *Allan, James A. 21 Bothwell-street, Glasgow.
1904. *Allcock, William Burt. Emmanuel College, Cambridge.
1879. *Allen, Rev. A. J. C. 34 Lensfield-road, Cambridge.
1898. §Allen, Dr. E. J. The Laboratory, Citadel Hill, Plymouth.
1891. ‡Allen, H. A., F.G.S. 28 Jermyn-street, S.W.
1907. *Allorge, M. M., L. ès Sc., F.G.S. University Museum, Oxford.
1912. *Allworthy, S. W., M.A., M.D. The Manor House, Antrim-road, Belfast.

Year of Election.

1882. *Alverstone, The Right Hon. Lord, G.C.M.G., LL.D., F.R.S. Winterfold, Cranleigh, Surrey.
1887. ‡Alward, G. L. Enfield Villa, Waltham, Grimsby, Yorkshire.
1883. §Amery, John Sparke. Druid, Ashburton, Devon.
1909. ‡Ami, H. M., M.D. Ottawa, Canada.
1884. ‡Ami, Henry, M.A., D.Sc., F.G.S. Geological Survey, Ottawa, Canada.
1910. ‡Anderson, Alexander. Tower House, Dore, near Sheffield.
1905. *Anderson, C. L. P.O. Box 2162, Johannesburg.
1912. ‡Anderson, E. M. 43 Ladysmith-road, Edinburgh.
1908. ‡Anderson, Edgar. Glenavon, Merrion-road, Dublin.
1885. *Anderson, Hugh Kerr, M.A., M.D., F.R.S. Caius College, Cambridge.
1901. *Anderson, James. 10 Albion-crescent, Dowanhill, Glasgow.
1892. ‡Anderson, Joseph, LL.D. 8 Great King-street, Edinburgh.
1899. *Anderson, Miss Mary Kerr. 13 Napier-road, Edinburgh.
1888. *Anderson, R. Bruce. 5 Westminster-chambers, S.W.
1887. ‡Anderson, Professor R. J., M.D., F.L.S. University College, and Atlantic Lodge, Salthill, Galway.
1901. *Anderson, Dr. W. Carrick. 7 Scott-street, Garnethill, Glasgow.
1908 ‡Anderson, William. Glenavon, Merrion-road, Dublin.
1911. ‡Andrade, E. N. da C. University College, Gower Street, W.C.
1907. ‡Andrews, A. W. Adela-avenue, West Barnes-lane, New Malden, Surrey.
1909. ‡Andrews, Alfred J. Care of Messrs. Andrews, Andrews, & Co., Winnipeg, Canada.
1895. ‡Andrews, Charles W., B.A., D.Sc., F.R.S. British Museum (Natural History), S.W.
1909. ‡Andrews, G. W. 433 Main-street, Winnipeg, Canada.
1880. *Andrews, Thornton, M.Inst.C.E. Cefn Eithen, Swansea.
1886. §Andrews, William, F.G.S. Steeple Croft, Coventry.
1877. §Angell, John, F.C.S., F.I.C. 6 Beacons-field, Derby-road, Withington, Manchester.
1912. §Angus, Miss Mary. 354 Blackness-road, Dundee.
1886. †Ansell, Joseph. 27 Bennett's-hill, Birmingham.
1901. ‡Arakawa, Minozi. Japanese Consulate, 84 Bishopsgate-street Within, E.C.
1900. *Arber, E. A. Newell, M.A., F.L.S. 52 Huntingdon-road, Cambridge.
1904. *Arber, Mrs. E. A. Newell, D.Sc., F.L.S. 52 Huntingdon-road, Cambridge.
1913. §Archer, J. Hillside, Crowcombe, West Somerset.
1913. *Archer, R. L., M.A., Professor of Education in University College, Bangor. Plas Menai, Bangor.
1894. ‡Archibald, A. Holmer, Court-road, Tunbridge Wells.
1884. *Archibald, E. Douglas. Constitutional Club, W.C.
1909. §Archibald, Professor E. H. Bowne Hall of Chemistry, Syracuse University, Syracuse, New York, U.S.A.
1909. ‡Archibald, H. Care of Messrs. Machray, Sharpe, & Dennistoun, Bank of Ottawa Chambers, Winnipeg, Canada.
1883. *Armistead, William. Hillcrest, Oaken, Wolverhampton.
1908. ‡Armstrong, E. C. R., M.R.I.A., F.R.G.S. Cyprus, Eglinton-road, Dublin.
1903. *Armstrong, E. Frankland, D.Sc., Ph.D. 27 Eastern-avenue, Reading.

Year of Election.

1873. *Armstrong, Henry E., Ph.D., LL.D., F.R.S. (Pres. B, 1885, 1909; Pres. L, 1902; Council, 1899–1905, 1909– .) 55 Granville-park, Lewisham, S.E.
1909. ‡Armstrong, Hon. Hugh. Parliament Buildings, Kennedy-street, Winnipeg, Canada.
1905. ‡Armstrong, John. Kamfersdam Mine, near Kimberley, Cape Colony.
1905. §Arnold, J. O., F.R.S., Professor of Metallurgy in the University of Sheffield.
1893. *Arnold-Bemrose, H. H., Sc.D., F.G.S. Ash Tree House, Osmaston-road, Derby.
1904. ‡Arunachalam, P. Ceylon Civil Service, Colombo, Ceylon.
1870. *Ash, Dr. T. Linnington. Penroses, Holsworthy, North Devon.
1903. *Ashby, Thomas, M.A., D.Litt. The British School, Rome.
1909. ‡Ashdown, J. H. 337 Broadway, Winnipeg, Canada.
1907. ‡Ashley, W. J., M.A. (Pres. F, 1907), Professor of Commerce in the University of Birmingham. 3 Yateley-road, Edgbaston, Birmingham.
Ashworth, Henry. Turton, near Bolton.
1903. *Ashworth, J. H., D.Sc. 4 Cluny-terrace, Edinburgh.
1890. ‡Ashworth, J. Reginald, D.Sc. 105 Freehold-street, Rochdale.
1875. *Aspland, W. Gaskell. 50 Park Hill-road, N.W.
1896. *Assheton, Richard, M.A., F.L.S. Grantchester, Cambridge.
1905. ‡Assheton, Mrs. Grantchester, Cambridge.
1908. §Astley, Rev. H. J. Dukinfield, M.A., Litt.D. East Rudham Vicarage, King's Lynn.
1898. *Atkinson, E. Cuthbert. 5 Pembroke-vale, Clifton, Bristol.
1894. *Atkinson, Harold W., M.A. West View, Eastbury-avenue, Northwood, Middlesex.
1906. ‡Atkinson, J. J. Cosgrove Priory, Stony Stratford.
1881. ‡Atkinson, J. T. The Quay, Selby, Yorkshire.
1907. ‡Atkinson, Robert E. Morland-avenue, Knighton, Leicester.
1881. ‡Atkinson, Robert William, F.C.S., F.I.C. (Local Sec. 1891.) 44 Stuart-street, Cardiff.
1906. §Auden, G. A., M.A., M.D. The Education Office, Edmund-street, Birmingham.
1907. §Auden, H. A., D.Sc. 13 Broughton-drive, Grassendale, Liverpool.
1903. ‡Austin, Charles E. 37 Cambridge-road, Southport.
1912. §Austin, P. C. 101 Norwood-road, Herne Hill, S.E.
1909. ‡Axtell, S. W. Stobart Block, Winnipeg, Canada.

1883. *Bach-Gladstone, Madame Henri. 147 Rue de Grenelle, Paris.
1863. ‡Backhouse, T. W. West Hendon House, Sunderland.
1883. *Backhouse, W. A. St. John's, Wolsingham, R.S.O., Durham.
1887. *Bacon, Thomas Walter. Ramsden Hall, Billericay, Essex.
1903. ‡Baden-Powell, Major B. 32 Prince's-gate, S.W.
1907. §Badgley, Colonel W. F., Assoc.Inst.C.E., F.R.G.S. Verecroft, Devizes.
1908. *Bagnall, Richard Siddoway. Hope Department of Zoology, University Museum, Oxford.
1905. ‡Baikie, Robert. P.O. Box 36, Pretoria, South Africa.
1883. ‡Baildon, Dr. 42 Hoghton-street, Southport.
1883. *Bailey, Charles, M.Sc., F.L.S. Haymesgarth, Cleeve Hill S.O., Gloucestershire.
1887. *Bailey, G. H., D.Sc., Ph.D. Edenmor, Kinlochleven, Argyll, N.B.
1905. *Bailey, Harry Percy. Montrose, Northdown, Margate.
1914. §Bailey, P. G. 4 Richmond-road, Cambridge.

Year of Election.

1905. ‡Bailey, Right Hon. W. F., C.B. Land Commission, Dublin.
1894. *BAILY, FRANCIS GIBSON, M.A. Newbury, Colinton, Midlothian.
1878. ‡BAILY, WALTER. 4 Roslyn-hill, Hampstead, N.W.
1905. *Baker, Sir Augustine. 56 Merrion-square, Dublin.
1913. *Baker, Bevan B., B.Sc. Frontenac, Donnington-road, Harlesden, N.W.
1910. §BAKER, H. F., Sc.D., F.R.S. (Pres. A., 1913), Lowndean Professor of Astronomy and Geometry in the University of Cambridge. St. John's College, Cambridge.
1886. §Baker, Harry, F.I.C. Epworth House, Moughland-lane, Runcorn.
1911. §Baker, Miss Lilian, M.Sc. Queen's-avenue, Tunstall, Staffordshire.
1913. §Baker, Ralph Homfeld. Cambridge.
1907. ‡Baldwin, Walter. 5 St. Alban's-street, Rochdale.
1904. ‡BALFOUR, The Right Hon. A. J., D.C.L., LL.D., M.P., F.R.S., Chancellor of the University of Edinburgh. (PRESIDENT, 1904.) Whittingehame, Prestonkirk, N.B.
1894. ‡BALFOUR, HENRY, M.A. (Pres. H, 1904.) Langley Lodge, Headington Hill, Oxford.
1905. ‡Balfour, Mrs. H. Langley Lodge, Headington Hill, Oxford.
1875. ‡BALFOUR, ISAAC BAYLEY, M.A., D.Sc., M.D., F.R.S., F.R.S.E., F.L.S. (Pres. D, 1894; K, 1901), Professor of Botany in the University of Edinburgh. Inverleith House, Edinburgh.
1883. ‡Balfour, Mrs. I. Bayley. Inverleith House, Edinburgh.
1905. ‡Balfour, Mrs. J. Dawyck, Stobo, N.B.
1905. ‡Balfour, Lewis. 11 Norham-gardens, Oxford.
1905. ‡Balfour, Miss Vera B. Dawyck, Stobo, N.B.
1878. *Ball, Sir Charles Bent, Bart., M.D., Regius Professor of Surgery in the University of Dublin. 24 Merrion-square, Dublin.
1913. *Ball, Sidney, M.A. St. John's College, Oxford.
1908. ‡Ball, T. Elrington. 6 Wilton-place, Dublin.
1883. *Ball, W. W. Rouse, M.A. Trinity College, Cambridge.
1905. ‡*Ballantine, Rev. T. R. Tirmochree, Bloomfield, Belfast.*
1869. ‡Bamber, Henry K., F.C.S. 5 Westminster-chambers, Victoria-street, Westminster, S.W.
1890. ‡Bamford, Professor Harry, M.Sc. 30 Falkland-mansions, Glasgow.
1909. ‡Bampfield, Mrs. E. 309 Donald-street, Winnipeg, Canada.
1912. *Bancroft, Miss Nellie, B.Sc., F.L.S. 260 Normanton-road, Derby.
1905. ‡Banks, Miss Margaret Pierrepont. 10 Regent-terrace, Edinburgh.
1898. ‡Bannerman, W. Bruce, F.S.A. 4 The Waldrons, Croydon.
1909. ‡Baragar, Charles A. University of Manitoba, Winnipeg, Canada.
1910. §Barber, Miss Mary. 13 Temple Fortune Court, Hendon, N.W.
1890. *Barber-Starkey, W. J. S. Aldenham Park, Bridgnorth, Salop.
1861. *Barbour, George. Bolesworth Castle, Tattenhall, Chester.
1860. *Barclay, Robert. High Leigh, Hoddesden, Herts.
1887. *Barclay, Robert. Sedgley New Hall, Prestwich, Manchester.
1913. §Barclay, Sir Thomas. The Uplands, Blackwell, Bromsgrove.
1902. ‡Barcroft, H., D.L. The Glen, Newry, Co. Down.
1902. ‡BARCROFT, JOSEPH, M.A., B.Sc., F.R.S. King's College, Cambridge.
1911. ‡Barger, George, M.A., D.Sc. 107 Tyrwhitt-road, St. John's. S.E.
1904. §Barker, B. T. P., M.A. Fenswood, Long Ashton, Bristol.
1906. *Barker, Geoffrey Palgrave. Henstead Hall, Wrentham, Suffolk.
1899. §Barker, John H., M.Inst.C.E. Adderley Park Rolling Mills, Birmingham.
1882. *Barker, Miss J. M. Sunny Bank, Scalby, Scarborough.
1910. *Barker, Raymond Inglis Palgrave. Henstead Hall, Wrentham, Suffolk.
1913. §BARLING, Dr. GILBERT. Blythe Court, Norfolk-road, Edgbaston, Birmingham.

Year of Election.

1909. ‡Barlow, Lieut.-Colonel G. N. H. Care of Messrs. Cox & Co., 16 Charing Cross, S.W.
1889. ‡Barlow, H. W. L., M.A., M.B., F.C.S. The Park Hospital, Hither Green, S.E.
1885. *Barlow, William, F.R.S., F.G.S. The Red House, Great Stanmore.
1905. *Barnard, Miss Annie T., M.D., B.Sc. Care of W. Barnard, Esq., 3 New-court, Lincoln's Inn, W.C.
1902. §Barnard, J. E. Park View, Brondesbury Park, N.W.
1881. *Barnard, William, LL.B. 3 New-court, Lincoln's Inn, W.C.
1904. ‡Barnes, Rev. E. W., M.A., Sc.D., F.R.S. Trinity College, Cambridge.
1907. §Barnes, Professor H. T., Sc.D., F.R.S. McGill University, Montreal, Canada.
1909. *Barnett, Miss Edith A. Holm Leas, Worthing.
1913. §Barnett, Thomas G. The Hollies, Upper Clifton-road, Sutton Coldfield.
1881. ‡Barr, Archibald, D.Sc., M.Inst.C.E. (Pres. G, 1912.) Caxton-street, Anniesland, Glasgow.
1902. *Barr, Mark. Gloucester-mansions, Harrington-gardens, S.W.
1904. ‡Barrett, Arthur. 6 Mortimer-road, Cambridge.
1872. *Barrett, Sir W. F., F.R.S., F.R.S.E., M.R.I.A. 6 De Vesci-terrace, Kingstown, Co. Dublin.
1874. *Barrington, R. M., M.A., LL.B., F.L.S. Fassaroe, Bray, Co. Wicklow.
1874. *Barrington-Ward, Rev. Mark J., M.A., F.L.S., F.R.G.S. The Rectory, Duloe S.O., Cornwall.
1893. *Barrow, George, F.G.S. 202 Brecknock-road, Tufnell Park, N.
1913. §Barrow, Harrison. 57 Wellington-street, Edgbaston, Birmingham.
1913. §Barrow, Louis. 155 Middleton Hall-road, King's Norton.
1913. §Barrow, Walter. 13 Ampton-road, Edgbaston, Birmingham.
1908. ‡Barry, Gerald H. Wiglin Glebe, Carlow, Ireland.
1884. *Barstow, Miss Frances A. Garrow Hill, near York.
1890. *Barstow, J. J. Jackson. The Lodge, Weston-super-Mare.
1890. *Barstow, Mrs. The Lodge, Weston-super-Mare.
1892. ‡Bartholomew, John George, F.R.S.E., F.R.G.S. Newington House, Edinburgh.
1858. *Bartholomew, William Hamond, M.Inst.C.E. Ridgeway House, Cumberland-road, Hyde Park, Leeds.
1909. ‡Bartleet, Arthur M. 138 Hagley-road, Edgbaston, Birmingham.
1909. ‡Bartlett, C. Bank of Hamilton-building, Winnipeg, Canada.
1893. *Barton, Edwin H., D.Sc., F.R.S.E., Professor of Experimental Physics in University College, Nottingham.
1908. ‡Barton, Rev. Walter John, M.A., F.R.G.S. The College, Winchester.
1904. *Bartrum, C. O., B.Sc. 32 Willoughby-road, Hampstead, N.W.
1888. *Basset, A. B., M.A., F.R.S. Fledborough Hall, Holyport, Berkshire.
1891. ‡Bassett, A. B. Cheverell, Llandaff.
1866. *Bassett, Henry. 26 Belitha-villas, Barnsbury, N.
1911. *Bassett, Henry, jun., D.Sc., Ph.D. University College, Reading.
1889. ‡Bastable, Professor C. F., M.A., F.S.S. (Pres. F, 1894.) 52 Brighton-road, Rathgar, Co. Dublin.
1871. ‡Bastian, H. Charlton, M.A., M.D., F.R.S., F.L.S., Emeritus Professor of the Principles and Practice of Medicine in University College, London. Fairfield, Chesham Bois, Bucks.
1912. ‡Bastian, Staff-Surgeon William, R.N. Chesham Bois, Buckinghamshire.
1883. ‡Bateman, Sir A. E., K.C.M.G. Woodhouse, Wimbledon Park, S.W.
1905. *Bateman, Mrs. F. D. Kilmorie, Ilsham-drive, Torquay, Devon.

Year of
Election.

1907. *Bateman, Harry. The University, Manchester.
1884. ‡Bateson, Professor William, M.A., F.R.S. (President Elect; Pres. D, 1904.) The Manor House, Merton, Surrey.
1914. §Bateson, Mrs. The Manor House, Merton, Surrey.
1881. *Bather, Francis Arthur, M.A., D.Sc., F.R.S., F.G.S. British Museum (Natural History), S.W.
1906. §Batty, Mrs. Braithwaite. Ye Gabled House, The Parks, Oxford.
1904. ‡Baugh, J. H. Agar. 92 Hatton-garden, E.C.
1909. §Bawlf, Nicholas Assiniboine-avenue, Winnipeg, Canada.
1913. §Bawtree, A. E., F.R.P.S. Lynton, Manor Park-road, Sutton, Surrey.
1912. *Baxter, Miss Evelyn V. Roselea, Kirkton of Largo, Fife.
1912. *Bayliss, W. M., M.A., D.Sc., F.R.S., Professor of General Physiology in University College, London, W.C.
1876. *Baynes, Robert E., M.A. Christ Church, Oxford.
1887. *Baynes, Mrs. R. E. 2 Norham-gardens, Oxford.
1883. *Bazley, Gardner S. Hatherop Castle, Fairford, Gloucestershire.
Bazley, Sir Thomas Sebastian, Bart., M.A. Kilmorie, Ilsham-drive, Torquay, Devon.
1909. *Beadnell, H. J. Llewellyn, F.G.S. Hafod, Llandinam, Montgomeryshire.
1889. §Beare, Professor T. Hudson, B.Sc., F.R.S.E., M.Inst.C.E. The University, Edinburgh.
1905. ‡Beare, Mrs. T. Hudson. 10 Regent-terrace, Edinburgh.
1904. ‡Beasley, H. C. 25A Prince Alfred-road, Wavertree, Liverpool.
1905. ‡Beattie, Professor J. C., D.Sc., F.R.S.E. South African College, Cape Town.
1900. ‡Beaumont, Professor Roberts, M.I.Mech.E. The University, Leeds
1885. *Beaumont, W. W., M.Inst.C.E. Outer Temple, 222 Strand, W.C.
1913. §Beaven, E. S. Eastway, Warminster.
1887. *Beckett, John Hampden. Corbar Hall, Buxton, Derbyshire.
1904. §Beckit, H. O. Cheney Cottage, Headington, Oxford.
1885. ‡Beddard, Frank E., M.A., F.R.S., F.Z.S., Prosector of the Zoological Society of London, Regent's Park, N.W.
1911. ‡Beddow, Fred, D.Sc., Ph.D. 2 Pier-mansions, Southsea.
1904. *Bedford, T. G., M.A. 13 Warkworth-street, Cambridge.
1891. ‡Bedlington, Richard. Gadlys House, Aberdare.
1878. ‡Bedson, P. Phillips, D.Sc., F.C.S. (Local Sec. 1889), Professor of Chemistry in the College of Physical Science, Newcastle-upon-Tyne.
1901. *Beilby, G. T., LL.D., F.R.S. (Pres. B, 1905.) 11 University-gardens, Glasgow.
1905. ‡Beilby, Hubert. 11 University-gardens, Glasgow.
1891. *Belinfante, L. L., M.Sc., Assist. Sec. G.S. Burlington House, W.
1909. ‡Bell, C. N. (Local Sec. 1909.) 121 Carlton-street, Winnipeg, Canada.
1894. ‡Bell, F. Jeffrey, M.A., F.Z.S. British Museum, S.W.
1900. *Bell, Henry Wilkinson. Beech Cottage, Rawdon, near Leeds.
1870. *Bell, J. Carter, A.R.S.M. The Cliff, Higher Broughton, Manchester.
1883. *Bell, John Henry. 102 Leyland-road, Southport.
1888. *Bell, Walter George, M.A. Trinity Hall, Cambridge.
1914. §Bell, William Reid, M.Inst.C.E. Burnie, Tasmania.
1908. *Bellamy, Frank Arthur, M.A., F.R.A.S. University Observatory, Oxford.
1904. ‡Bellars, A. E. Magdalene College, Cambridge.

Year of Election.

1913. *Belliss, John, M.I.M.E. Darlinghurst, Carpenter-road, Edgbaston, Birmingham.
1883. *Bennett, Laurence Henry. The Elms, Paignton, South Devon.
1901. ‡Bennett, Professor Peter. 207 Bath-street, Glasgow.
1909. *Bennett, R. B., K.C. Calgary, Alberta, Canada.
1909. ‡Benson, Miss C. C. Terralta, Port Hope, Ontario, Canada.
1903. §Benson, D. E. Queenwood, 12 Irton-road, Southport.
1901. *Benson, Miss Margaret J., D.Sc. Royal Holloway College, Englefield Green.
1887. *Benson, Mrs. W. J. 5 Wellington-court, Knightsbridge, S.W.
1898. *Bent, Mrs. Theodore. 13 Great Cumberland-place, W.
1904. ‡Bentley, B. H., M.A., Professor of Botany in the University of Sheffield.
1905. *Bentley, Wilfred. The Dene, Kirkheaton, Huddersfield.
1908. ‡*Benton, Mrs. Evelyn M. Kingswear, Hale, Altrincham, Cheshire.*
1896. *Bergin, William, M.A., Professor of Natural Philosophy in University College, Cork.
1894. §Berkeley, The Earl of, F.R.S., F.C.S. (Council, 1909–10.) Foxcombe, Boarshill, near Abingdon.
1905. *Bernacchi, L. C., F.R.G.S. 54 Inverness-terrace, W.
1906. *Bernays, Albert Evan. 3 Priory-road, Kew, Surrey.
1898. §Berridge, Miss C. E. 48 Stratford-road, Marloes-road, Kensington, W.
1894. §Berridge, Douglas, M.A., F.C.S. The College, Malvern.
1908. *Berridge, Miss Emily M. Dunton Lodge, The Knoll, Beckenham.
1908. *Berry, Arthur J. 14 Regent-street, Cambridge.
1904. §Berry, R. A., Ph.D., West of Scotland Agricultural College, 6 Blythswood-square, Glasgow.
1905. ‡Bertrand, Captain Alfred. Champel, Geneva.
1862. ‡Besant, William Henry, M.A., Sc.D., F.R.S. St. John's College, Cambridge.
1913. §Bethune-Baker, G. T. 19 Clarendon-road, Edgbaston, Birmingham.
1880. *Bevan, Rev. James Oliver, M.A., F.S.A., F.G.S. Chillenden Rectory, Canterbury.
1913. §Bevan, Mrs. Hillside, Egham.
1906. ‡*Bevan-Lewis, W., M.D. West Riding Asylum, Wakefield.*
1884. *Beverley, Michael, M.D. 54 Prince of Wales-road, Norwich.
1913. §Bewlay, Hubert. The Lindens, Moseley, Birmingham.
1903. ‡Bickerdike, C. F. 1 Boverney-road, Honor Oak Park, S.E.
1870. ‡Bickerton, Professor A. W. 18 Pembridge-mansions, Moscow-road, W.
1888. *Bidder, George Parker. Savile Club, Piccadilly, W.
1910. ‡*Biddlecombe, A. 50 Grainger-street, Newcastle-on-Tyne.*
1882. ‡*Biggs, C. H. W., F.C.S. Glebe Lodge, Champion-hill, S.E.*
1911. §Biles, Sir John H., LL.D., D.Sc. (Pres. G., 1911), Professor of Naval Architecture in the University of Glasgow. 10 University-gardens, Glasgow.
1898. ‡Billington, Charles. Heimath, Longport, Staffordshire.
1901. *Bilsland, Sir William, Bart., J.P. 28 Park-circus, Glasgow.
1908. *Bilton, Edward Barnard. Graylands, Wimbledon Common, S.W.
1887. *Bindloss, James B. Elm Bank, Buxton.
1884. *Bingham, Colonel Sir John E., Bart. West Lea, Ranmoor, Sheffield.
1881. ‡Binnie, Sir Alexander R., M.Inst.C.E., F.G.S. (Pres. G, 1900.) 77 Ladbroke-grove, W.
1910. *Birchenough, C., M.A. 8 Severn-road, Sheffield.
1887. *Birley, H. K. Penrhyn, Irlams o' th' Height, Manchester.

Year of Election.

1913. §Birtwistle, G. Pembroke College, Cambridge.
1904. ‡Bishop, A. W. Edwinstowe, Chaucer-road, Cambridge.
1911. *Bishop, Major C. F., R.A. The Castle, Tynemouth, Northumberland.
1906. §Bishop, J. L. Yarrow Lodge, Waldegrave-road, Teddington.
1910. ‡Bisset, John. Thornhill, Insch, Aberdeenshire.
1886. *Bixby, General W. H. 735 Southern-building, Washington, U.S.A.
1909. ‡Black, W. J., Principal of Manitoba Agricultural College, Winnipeg, Canada.
1901. §Black, W. P. M. 136 Wellington-street, Glasgow.
1903. *Blackman, F. F., M.A., D.Sc., F.R.S. (Pres. K, 1908.) St. John's College, Cambridge.
1908. §Blackman, Professor V. H., M.A., Sc.D., F.R.S. Imperial College of Science and Technology, S.W.
1913. §Blackwell, Miss Elsie M., M.Sc. 18 Stanley-avenue, Birkdale, Southport.
1913. §Bladen, W. Wells. Stone, Staffordshire.
1909. ‡Blaikie, Leonard, M.A. Civil Service Commission, Burlington-gardens, W.
1910. ‡Blair, R., M.A. London County Council, Spring-gardens, S.W.
1902. ‡Blake, Robert F., F.I.C. Queen's College, Belfast.
1900. *Blamires, Joseph. Bradley Lodge, Huddersfield.
1905. ‡Blamires, Mrs. Bradley Lodge, Huddersfield.
1904. ‡Blanc, Dr. Gian Alberto. Istituto Fisico, Rome.
1884. *Blandy, William Charles, M.A. 1 Friar-street, Reading.
1887. *Bles, Edward J., M.A., D.Sc. Elterholm, Madingley-road, Cambridge.
1884. *Blish, William G. Niles, Michigan, U.S.A.
1913. §Blofield, Rev. S., B.A. Saltley College, Birmingham.
1902. ‡Blount, Bertram, F.I.C. 76 & 78 York-street, Westminster, S.W.
1888. ‡Bloxsom, Martin, B.A., M.Inst.C.E. 4 Lansdowne-road, Crumpsall Green, Manchester.
1909. §Blumfield, Joseph, M.D. 35 Harley-street, W.
Blyth, B. Hall. 135 George-street, Edinburgh.
1887. *Boddington, Henry. Pownall Hall, Wilmslow, Manchester.
1908. §Boeddicker, Otto, Ph.D. Birr Castle Observatory, Birr, Ireland.
1887. *Boissevain, Gideon Maria. 4 Tesselschade-straat, Amsterdam.
1911. §Bolland, B. G. C. Department of Agriculture, Cairo, Egypt.
1898. §Bolton, H., F.R.S.E. The Museum, Queen's-road, Bristol.
1894. §Bolton, John, F.R.G.S. Brooklyn, 87 Widmore Road, Bromley, Kent.
1898. *Bonar, James, M.A., LL.D. (Pres. F, 1898; Council, 1899–1905.) The Mint, Ottawa, Canada.
1909. ‡Bonar, Thomson, M.D. 114 Via Babuino, Piazza di Spagna, Rome.
1912. *Bond, C. I., F.R.C.S. Springfield-road, Leicester.
1909. ‡Bond, J. H. R., M.B. 167 Donald-street, Winnipeg, Canada.
1908. ‡Bone, Professor W. A., D.Sc., F.R.S. Imperial College of Science and Technology, S.W.
1913. §Bonnar, W., LL.B., Ph.D. Cecil Hotel, Strand, W.C.
1871. *Bonney, Rev. Thomas George, Sc.D., LL.D., F.R.S., F.S.A., F.G.S. (President, 1910; Secretary, 1881–85; Pres. C, 1886.) 9 Scroope-terrace, Cambridge.
1911. ‡Bonny, W. Naval Store office, The Dockyard, Portsmouth.
1888. ‡Boon, William. Coventry.
1893. ‡Boot, Sir Jesse. Carlyle House, 18 Burns-street, Nottingham.
1890. *Booth, Right Hon. Charles, Sc.D., F.R.S., F.S.S. 28 Campden House Court, Kensington, W.
1883. ‡Booth, James. Hazelhurst, Turton.

Year of
Election.

1910. §Booth, John, M.C.E., B.Sc. The Gables, Berkeley-street, Hawthorn, Melbourne. Australia.
1883. ‡Boothroyd, Benjamin. Weston-super-Mare.
1901. **Boothroyd, Herbert E., M.A., B.Sc.* *Sidney Sussex College, Cambridge.*
1912. ‡Borgmann, Professor J. J., D.Ph., LL.D. Physical Institute, The University, St. Petersburg.
1882. §BORNS, HENRY, Ph.D. 5 Sutton Court-road, Chiswick, W.
1901. ‡Borradaile, L. A., M.A. Selwyn College, Cambridge.
1903. *BOSANQUET, ROBERT C., M.A., Professor of Classical Archæology in the University of Liverpool. Institute of Archæology, 40 Bedford-street, Liverpool.
1896. ‡Bose, Professor J. C., C.I.E., M.A., D.Sc. Calcutta, India.
1881. §BOTHAMLEY, CHARLES H., M.Sc., F.I.C., F.C.S., Education Secretary, Somerset County Council, Weston-super-Mare.
1871. *BOTTOMLEY, JAMES THOMSON, M.A., LL.D., D.Sc., F.R.S., F.R.S.E., F.C.S. 13 University-gardens, Glasgow.
1884. *Bottomley, Mrs. 13 University-gardens, Glasgow.
1892. *BOTTOMLEY, W. B., M.A., Professor of Botany in King's College, W.C.
1909. §Boulenger, C. L., M.A., D.Sc. The University, Birmingham.
1905. §BOULENGER, G. A., F.R.S. (Pres. D, 1905.) 8 Courtfield-road, S.W.
1905. §Boulenger, Mrs. 8 Courtfield-road, S.W.
1903. §BOULTON, W. S., D.Sc., F.G.S., Professor of Geology in the University of Birmingham.
1911. ‡Bourdillon, R. Balliol College, Oxford.
1883. ‡BOURNE, Sir A. G., K.C.I.E., D.Sc., F.R.S., F.L.S. Old College, Nungumbakam, Madras.
1914. §Bourne, Lady. Old College, Nungumbakam, Madras.
1893. *BOURNE, G. C., M.A., D.Sc., F.R.S., F.L.S. (Pres. D, 1910 ; Council, 1903-09 ; Local Sec. 1894), Linacre Professor of Comparative Anatomy in the University of Oxford. Savile House, Mansfield-road, Oxford.
1904. *Bousfield, E. G. P. St. Swithin's, Hendon, N.W.
1913. §Bowater, W. H. Elm House, Arthur-road, Edgbaston, Birmingham.
1913. §Bowater, William. 20 Russell-road, Moseley, Birmingham.
1881. *BOWER, F. O., D.Sc., F.R.S., F.R.S.E., F.L.S. (Pres. K, 1898 ; Council, 1900–06), Regius Professor of Botany in the University of Glasgow.
1898. *Bowker, Arthur Frank, F.R.G.S., F.G.S. Whitehill, Wrotham, Kent.
1908. §Bowles, E. Augustus, M.A., F.L.S. Myddelton House, Waltham Cross, Herts.
1898. ‡BOWLEY, A. L., M.A. (Pres. F, 1906 ; Council, 1906–11.) North-court-avenue, Reading.
1880. ‡Bowly, Christopher. Cirencester.
1887. ‡Bowly, Mrs. Christopher. Cirencester.
1899. *BOWMAN, HERBERT LISTER, M.A., D.Sc., F.G.S., Professor of Mineralogy in the University of Oxford. Magdalen College, Oxford.
1899. *Bowman, John Herbert. Greenham Common, Newbury.
1887. §Box, Alfred Marshall. 14 Magrath Avenue, Cambridge.
1901. ‡Boyd, David T. Rhinsdale, Ballieston, Lanark.
1892. ‡BOYS, CHARLES VERNON, F.R.S. (Pres. A, 1903 ; Council, 1893–99, 1905–08.) 66 Victoria-street, S.W.
1872. *BRABROOK, Sir EDWARD, C.B., F.S.A. (Pres. H, 1898 ; Pres. F, 1903 ; Council, 1903–10, 1911–). 178 Bedford-hill, Balham, S.W.

Year of Election.

1894. *Braby, Ivon. Helena, Alan-road, Wimbledon, S.W.
1893. §Bradley, F. L. Ingleside, Malvern Wells.
1904. *Bradley, Gustav. Council Offices, Goole.
1903. *Bradley, O. Charnock, D.Sc., M.D., F.R.S.E. Royal Veterinary College, Edinburgh.
1892. ‡Bradshaw, W. Carisbrooke House, The Park, Nottingham.
1863. ‡Brady, George S., M.D., LL.D., F.R.S. Park Hurst, Endcliffe, Sheffield.
1911. §Bragg, W. H., M.A., F.R.S. (Council, 1913–), Professor of Physics in the University of Leeds.
1905. §Brakhan, A. Clare Bank, The Common, Sevenoaks.
1906. ‡Branfield, Wilfrid. 4 Victoria-villas, Upperthorpe, Sheffield.
1885. *Bratby, William, J.P. Alton Lodge, Lancaster Park, Harrogate.
1905 ‡Brausewetter, Miss. Roedean School, near Brighton.
1909. §Bremner, Alexander. 38 New Broad-street, E.C.
1905. ‡Bremner, R. S. Westminster-chambers, Dale-street, Liverpool.
1905. ‡Bremner, Stanley. Westminster-chambers, Dale-street, Liverpool.
1913. §Brenchley, Miss Winifred E., D.Sc., F.L.S. Rothamsted Experimental Station, Harpenden, Herts.
1902. *Brereton, Cloudesley. Briningham House, Briningham, S.O., Norfolk.
1909. *Breton, Miss Adela C. Care of Wilts and Dorset Bank, Bath.
1905. §Brewis, E. 27 Winchelsea-road, Tottenham, N.
1908. §Brickwood, Sir John. Branksmere, Southsea.
1907. *Bridge, Henry Hamilton. Fairfield House, Droxford, Hants.
1912. ‡Bridgman, F. J., F.L.S. Zoological Department, University College, W.C.
1913. §Brierley, Leonard H. 11 Ampton-road, Edgbaston, Birmingham.
1913. §Briggs, W. Lowther House, Hale, Cheshire.
1904. *Briggs, William, M.A., LL.D., F.R.A.S. Burlington House, Cambridge.
1909. *Briggs, Mrs. William. Owlbrigg, Cambridge.
1908. ‡Brindley, H. H. 4 Devana-terrace, Cambridge.
1893. ‡Briscoe, Albert E., B.Sc., A.R.C.Sc. The Hoppet, Little Baddow, Chelmsford.
1904. ‡Briscoe, J. J. Bourn Hall, Bourn, Cambridge.
1905. §Briscoe, Miss. Bourn Hall, Bourn, Cambridge.
1898. ‡Bristol, The Right Rev. G. F. Browne, D.D., Lord Bishop of. 17 The Avenue, Clifton, Bristol.
1879. *Brittain, W. H., J.P., F.R.G.S. Storth Oaks, Sheffield.
1905. **Broadwood, Brigadier-General R. G. The Deodars, Bloemfontein, South Africa.*
1905. ‡Brock, Dr. B. G. P.O. Box 216, Germiston, Transvaal.
1907. ‡Brockington, W. A., M.A. Birstall, Leicester.
1896. *Brocklehurst, S. Olinda, Sefton Park, Liverpool.
1901. ‡Brodie, T. G., M.D., F.R.S., Professor of Physiology in the University of Toronto. TheUniversity, Toronto, Canada.
1883. *Brodie-Hall, Miss W. L. Havenwood, Peaslake, Gomshall, Surrey.
1903. ‡Brodrick, Harold, M.A., F.G.S. (Local Sec. 1903.) 7 Aughton-road, Birkdale, Southport.
1913. §Brodrick, Mrs. Harold. 7 Aughton-road, Birkdale, Southport.
1904. ‡Bromwich, T. J. I'A., M.A., F.R.S. 1 Selwyn-gardens, Cambridge.
1906. ‡Brook, Stanley. 18 St. George's-place, York.
1911. §Brooke, Colonel Charles, K., F.R.G.S. Army and Navy Club, Pall Mall, S.W.
1906. *Brooks, F. T. 31 Tenison-avenue, Cambridge.
1883. *Brough, Mrs. Charles S. 4 Spencer-road, Southsea.

Year of Election.

1886. ‡Brough, Joseph, LL.D., Professor of Logic and Philosophy in University College, Aberystwyth.
1913. §Brown, Professor A. J., M.Sc., F.R.S. West Heath House, Northfield, Birmingham.
1905. ‡Brown, A. R. Trinity College, Cambridge.
1863. *BROWN, ALEXANDER CRUM, M.D., LL.D., F.R.S., F.R.S.E., V.P.C.S. (Pres. B, 1874; Local Sec. 1871.) 8 Belgrave-crescent, Edinburgh.
1883. ‡Brown, Mrs. Ellen F. Campbell. 27 Abercromby-square, Liverpool.
1905. §Brown, Professor Ernest William, M.A., D.Sc., F.R.S. Yale University, New Haven, Conn., U.S.A.
1903. ‡Brown, F. W. 6 Rawlinson-road, Southport.
1870. §BROWN, HORACE T., LL.D., F.R.S., F.G.S. (Pres. B, 1899; Council, 1904–11.) 52 Nevern-square, S.W.
1881. *Brown, John, M.D. Rosebank, Cape of Good Hope.
1895. *Brown, John Charles. 39 Burlington-road, Sherwood, Nottingham.
1882. *Brown, Mrs. Mary. Rosebank, Cape of Good Hope.
1898. §Brown, Nicol, F.G.S. 4 The Grove, Highgate, N.
1901. ‡Brown, Professor R. N. Rudmose, D.Sc. The University, Sheffield.
1913. §Brown, Robert. 4 Whitehouse-terrace, Edinburgh.
1908. §BROWN, SIDNEY G. 52 Kensington Park-road, W.
1905. §Brown, Mrs. Sidney G. 52 Kensington Park-road, W.
1910. *Brown, Sidney J. R. 52 Kensington Park-road, W.
1912. ‡Brown, T. Graham. The University, Liverpool.
1884. ‡Brown, W. G. University of Missouri, Columbia, Missouri, U.S.A.
1908. ‡Brown, William, B.Sc. 48 Dartmouth-square, Dublin.
1912. ‡Brown, Dr. William. Thornfield, Horley, Surrey.
1906. ‡Browne, Charles E., B.Sc. Christ's Hospital, West Horsham.
1900. *BROWNE, FRANK BALFOUR, M.A., F.R.S.E., F.Z.S. 26 Barton-road, Cambridge.
2908. ‡Browne, Rev. Henry, M.A. University College, Dublin.
1895. *Browne, H. T. Doughty. 6 Kensington House, Kensington-court, W.
1879. ‡BROWNE, Sir J. CRICHTON, M.D., LL.D., F.R.S., F.R.S.E. 41 Hans-place, S.W.
1905. *Browne, James Stark, F.R.A.S. Hillcrest, Castlebar-hill, Ealing, W.
1883. ‡Browning, Oscar, M.A. King's College, Cambridge.
1912. §Browning, T. B., M.A. 19 Aldermary-road, Bromley, Kent.
1905. §BRUCE, Colonel Sir DAVID, C.B., F.R.S., A.M.S. (Pres. I, 1905). Royal Society Commission, Kasu Hill (near Mvera), Central Angoniland, Nyasaland Protectorate, British Central Africa.
1905. ‡Bruce, Lady. 3P Artillery-mansions, Victoria-street, S.W.
1893. ‡BRUCE, WILLIAM S., LL.D., F.R.S.E. Scottish Oceanographical Laboratory, Surgeons' Hall, Edinburgh.
1902. ‡*Bruce-Kingsmill, Major J., F.C.S. 4 St. Ann's-square, Manchester.*
1900. *Brumm, Charles. Lismara, Grosvenor-road, Birkdale, Southport.
1896. *Brunner, Right Hon. Sir J. T., Bart. Silverlands, Chertsey.
1868. ‡BRUNTON, Sir T. LAUDER, Bart., M.D., Sc.D., F.R.S. (Council, 1908–12.) 10 Stratford-place, Cavendish-square, W.
1897. *Brush, Charles F. Cleveland, Ohio, U.S.A.
1886. *BRYAN, G. H., D.Sc., F.R.S., Professor of Mathematics in University College, Bangor.

Year of Election.

1894. ‡Bryan, Mrs. R. P. Plas Gwyn, Bangor.
1884. *BRYCE, Rev. Professor GEORGE, D.D., LL.D. Kilmadock, Winnipeg, Canada.
1909. ‡Bryce, Thomas H., M.D., Professor of Anatomy in the University of Glasgow. 2 The College, Glasgow.
1902. *Bubb, Miss E. Maude. Ullenwood, near Cheltenham.
1890. §Bubb, Henry. Ullenwood, near Cheltenham.
1902. *BUCHANAN, Miss FLORENCE, D.Sc. University Museum, Oxford.
1905. §Buchanan, Hon. Sir John. Clareinch, Claremont, Cape Town.
1871. ‡BUCHANAN, JOHN YOUNG, M.A., F.R.S., F.R.S.E., F.R.G.S., F.C.S. 26 Norfolk-street, Park-lane, W.
1909. ‡Buchanan, W. W. P.O. Box 1658, Winnipeg, Canada.
1913. §Buckland, H. T. 21 Yateley-road, Edgbaston, Birmingham.
1884. *Buckmaster, Charles Alexander, M.A., F.C.S. 16 Heathfield-road, Mill Hill Park, W.
1904. ‡Buckwell, J. C. North Gate House, Pavilion, Brighton.
1893. §BULLEID, ARTHUR, F.S.A. Dymboro, Midsomer Norton, Bath.
1913. *Bulleid, C. H. University College, Nottingham.
1913. *Buller, A. H. Reginald, Professor of Botany in the University of Manitoba, Winnipeg.
1909. ‡BULYEA, The Hon. G. H. V. Edmonton, Alberta, Canada.
1905. ‡Burbury, Mrs. A. A. 15 Melbury-road, W.
1905. ‡Burbury, Miss A. D. 15 Melbury road, W.
1907. ‡Burch, George J., M.A., D.Sc., F.R.S. 28 Norham-road, Oxford.
1881. ‡Burdett-Coutts, William Lehmann, M.P. 1 Stratton-street, Piccadilly, W.
1905. ‡BURDON, E. R., M.A. Ikenhilde, Royston, Herts.
1913. §Burfield, Stanley Thomas. 137 Woodchurch-road, Prenton, Birkenhead.
1913. *Burgess, J. Howard. Shide, Newport, Isle of Wight.
1894. ‡BURKE, JOHN B. B. Trinity College, Cambridge.
1884. *Burland, Lieut.-Colonel Jeffrey H. 342 Sherbrooke-street West, Montreal, Canada.
1899. ‡Burls, H. T., F.G.S. 2 Verulam-buildings, Gray's Inn, W.C.
1904. ‡Burn, R. H. 21 Stanley-crescent, Notting-hill, W.
1909. ‡Burns, F. D. 203 Morley-avenue, Winnipeg, Canada.
1908. ‡Burnside, W. Snow, D.Sc., Professor of Mathematics in the University of Dublin. 35 Raglan-road, Dublin.
1905. ‡Burroughes, James S., F.R.G.S. The Homestead, Seaford, Sussex.
1909. ‡Burrows, Theodore Arthur. 187 Kennedy-street, Winnipeg, Canada.
1910. ‡Burt, Cyril. The University, Liverpool.
1894. ‡Burton, C. V. Boar's Hill, Oxford.
1909. ‡Burton, E. F. 129 Howland-avenue, Toronto, Canada.
1911. §Burton, J. H. County Education Office, Weston-super-Mare.
1892. ‡Burton-Brown, Colonel A., F.G.S. Royal Societies Club, St. James's-street, S.W.
1904. ‡Burtt, Arthur H., D.Sc. 4 South View, Holgate, York.
1906. ‡Burtt, Philip. Swarthmore, St. George's-place, York.
1909. ‡Burwash, E. M., M.A. New Westminster, British Columbia, Canada.
1887. *Bury, Henry. Mayfield House, Farnham, Surrey.
1899. ‡Bush, Anthony. 43 Portland-road, Nottingham.
1895. ‡Bushe, Colonel C. K., F.G.S. 19 Cromwell-road, S.W.
1908. *Bushell, W. F. Rossall School, Fleetwood.
1910. ‡Butcher, Miss. 25 Earl's Court-square, S.W.

Year of Election.

1884. *Butcher, William Deane, M.R.C.S.Eng. Holyrood, 5 Cleveland-road, Ealing, W.
1913. *Butler, W. Waters. Southfield, Norfolk-road, Edgbaston, Birmingham.
1884. *Butterworth, W. Carisbrooke, Rhin-road, Colwyn Bay, North Wales.
1887. *Buxton, J. H. Clumber Cottage, Montague-road, Felixstowe.
1899. ‡Byles, Arthur R. 'Bradford Observer,' Bradford, Yorkshire.

1913. §Cadbury, Edward. Westholme, Selly Oak, Birmingham.
1913. §Cadbury, W. A. Wast Hills, King's Norton.
1892. ‡Cadell, H. M., B.Sc., F.R.S.E. Grange, Linlithgow.
1908. ‡Cadic, Edouard, D.Litt. Mon Caprice, Pembroke Park, Dublin.
1913. §Cadman, John, D.Sc., Professor of Mining in the University of Birmingham. 61 Wellington-road, Edgbaston, Birmingham.
1913. §Cadman, W. H., B.Sc. Matarieh, Cairo, Egypt.
1913. §Cahill, J. R. 49 Hanover Gate-mansions, Regent's Park, N.W.
1912. §Caine, Nathaniel. Spital, Cheshire.
1861. *CAIRD, Sir JAMES KEY, Bart., LL.D. 8 Magdalen Yard-road, Dundee.
1901. ‡Caldwell, Hugh. Blackwood, Newport, Monmouthshire.
1907. ‡Caldwell, K. S. St. Bartholomew's Hospital, S.E.
1908. §Caldwell, Colonel R. T., M.A., LL.M., LL.D., Master of Corpus Christi College, Cambridge.
1897. ‡CALLENDAR, HUGH L., M.A., LL.D., F.R.S. (Pres. A, 1912; Council, 1900–06), Professor of Physics in the Imperial College of Science and Technology, S.W.
1911. ‡Calman, W. T., D.Sc. British Museum (Natural History), Cromwell-road, S.W.
1911. §Cameron, Alexander T. Physiological Department, University of Manitoba, Winnipeg.
1857. ‡CAMERON, Sir CHARLES A., C.B., M.D. 51 Pembroke-road, Dublin.
1909. ‡Cameron, D. C. 65 Roslyn-road, Winnipeg, Canada.
1896. §Cameron, Irving H., LL.D., Professor of Surgery in the University of Toronto. 307 Sherbourne-street, Toronto, Canada.
1909. ‡Cameron, Hon. Mr. Justice J. D. Judges' Chambers, Winnipeg, Canada.
1901. §Campbell, Archibald. Park Lodge, Albert-drive, Pollokshields, Glasgow.
1897. ‡Campbell, Colonel J. C. L. Achalader, Blairgowrie, N.B.
1909. *Campbell, R. J. Rideau Hall, 85 Kennedy-street, Winnipeg, Canada.
1909. ‡Campbell, Mrs. R. J. Rideau Hall, 85 Kennedy-street, Winnipeg, Canada.
1902. ‡Campbell, Robert. 21 Great Victoria-street, Belfast.
1912. ‡Campbell, Dr. Robert. Geological Department, The University, Edinburgh.
1890. ‡CANNAN, Professor EDWIN, M.A., LL.D., F.S.S. (Pres. F, 1902.) 11 Chadlington-road, Oxford.
1905. ‡Cannan, Gilbert. King's College, Cambridge.
1897. §Cannon, Herbert. Alconbury, Bexley Heath, Kent.
1904. ‡Capell, Rev. G. M. Passenham Rectory, Stony Stratford.
1911. §Capon, R. S. 49A Rodney-street, Liverpool.
1905. *Caporn, Dr. A. W. Muizenberg, South Africa.
1894. ‡CAPPER, D. S., M.A., Professor of Mechanical Engineering in King's College, W.C.
1887. ‡CAPSTICK, J. W. Trinity College, Cambridge.

Year of Election.

1896. *Carden, H. Vandeleur. Fir Lodge, Broomfield, Chelmsford.
1913. §Carlier, E. Wace, M.Sc., M.D., F.R.S.E., Professor of Physiology in the University of Birmingham. The University, Edmund-street, Birmingham.
1913. §Carpenter, C. 157 Victoria-street, S.W
1913. *Carpenter, G. D. H., M.B. 19 Bardwell-road, Oxford.
1902. ‡Carpenter, G. H., B.Sc., Professor of Zoology in the Royal College of Science, Dublin.
1906. *Carpenter, H. C. H. 11 Oak-road, Withington, Manchester.
1905. §Carpmael, Edward, F.R.A.S., M.Inst.C.E. 24 Southampton-buildings, Chancery-lane, W.C.
1912. *Carr, H. Wildon, D.Litt. More's Garden, Cheyne-walk, S.W.
1910. §Carr, Henry F. Broadparks, Pinhoe, near Exeter.
1893. ‡Carr, J. Wesley, M.A., F.L.S., F.G.S., Professor of Biology in University College, Nottingham.
1906. *Carr, Richard E. Sylvan Mount, Sylvan-road, Upper Norwood, S.E.
1889. ‡Carr-Ellison, John Ralph. Hedgeley, Alnwick.
1911. ‡Carruthers, R. G., F.G.S. Geological Survey Office, 33 George-square, Edinburgh.
1867. ‡Carruthers, William, F.R.S., F.L.S., F.G.S. (Pres. D, 1886.) 44 Central-hill, Norwood, S.E.
1886. ‡Carslake, J Barham. (Local Sec. 1886.) 30 Westfield-road, Birmingham.
1899. ‡Carslaw, H. S., D.Sc., Professor of Mathematics in the University of Sydney, N.S.W.
1911. ‡Carter, Godfrey, M.B. 4 Lawson-road, Broomhill, Sheffield.
1900. *Carter, W. Lower, M.A., F.G.S. Bolbec, Grange Road, Watford.
1896. ‡Cartwright, Miss Edith G. 21 York Street-chambers, Bryanston-square, W.
1878. *Cartwright, Ernest H., M.A., M.D. Myskyns, Ticehurst, Sussex.
1870. §Cartwright, Joshua, M.Inst.C.E., F.S.I. 21 Parsons-lane, Bury, Lancashire.
1862. ‡Carulla, F. J. R. 84 Rosehill-street, Derby.
1894. ‡Carus, Dr. Paul. La Salle, Illinois, U.S.A.
1913. §Carus-Wilson, Cecil, F.R.S.E., F.G.S. 16 Waldegrave-park, Strawberry Hill, Twickenham.
1901. ‡Carver, Thomas A. B., D.Sc., Assoc.M.Inst.C.E. 9 Springfield-road, Dalmarnock, Glasgow.
1899. *Case, J. Monckton. Department of Lands (Water Branch), Victoria, British Columbia.
1897. *Case, Willard E. Auburn, New York, U.S.A.
1873. *Cash, William, F.G.S. 26 Mayfield-terrace South, Halifax.
1908. *Cave, Charles J. P., M.A. Ditcham Park, Petersfield.
1910. §Chadburn, A. W. Brincliffe Rise, Sheffield.
1905. *Challenor, Bromley, M.A. The Firs, Abingdon.
1905. *Challenor, Miss E. M. The Firs, Abingdon.
1910. §Chalmers, Stephen D. 25 Cornwall-road, Stroud Green, N.
1913. §Chalmers, Mrs. S. D. 25 Cornwall-road, Stroud Green, N.
1913. §Chamberlain, Neville. Westbourne, Edgbaston, Birmingham.
1913. §Chambers, Miss Beatrice Anne. Glyn-y-mêl, Fishguard.
1901. §Chamen, W. A. South Wales Electrical Power Distribution Company, Royal-chambers, Queen-street, Cardiff.
1905. ‡Champion, G. A. Haraldene, Chelmsford-road, Durban, Natal.
1881. *Champney, John E. 27 Hans-place, S.W.
1908. ‡Chance, Sir Arthur, M.D. 90 Merrion-square, Dublin.
1888. ‡Chandler, S. Whitty, B.A. St. George's, Cecil-road, Boscombe.

Year of Election.

1907. *Chapman, Alfred Chaston, F.I.C. 8 Duke-street, Aldgate, E.C.
1902. *Chapman, D. L., F.R.S. Jesus College, Oxford.
1910. ‡Chapman, J. E. Kinross.
1899. §CHAPMAN, Professor SYDNEY JOHN, M.A., M.Com. (Pres. F, 1909.) Burnage Lodge, Levenshulme, Manchester.
1912. *Chapman, Sydney, D.Sc., B.A., F.R.A.S. Royal Observatory, Greenwich, S.E.
1910. ‡Chappell, Cyril. 73 Neill-road, Sheffield.
1905. ‡Chassigneux, E. 12 Tavistock-road, Westbourne-park, W.
1904. *Chattaway, F. D., M.A., D.Sc., Ph.D., F.R.S. 151 Woodstock-road, Oxford.
1886. *CHATTOCK, A. P., D.Sc. Heathfield Cottage, Crowcombe, Somerset.
1904. *Chaundy, Theodore William, M.A. Christ Church, Oxford.
1913. §Cheesman, Miss Gertrude Mary. The Crescent, Selby.
1900. *Cheesman, W. Norwood, J.P., F.L.S. The Crescent, Selby.
1874. *Chermside, Lieut.-General Sir Herbert, R.E., G.C.M.G., C.B. Newstead Abbey, Nottingham.
1908. ‡Cherry, Right Hon. Lord Justice. 92 St. Stephen's Green, Dublin.
1910. ‡Chesney, Miss Lilian M., M.B. 381 Glossop-road, Sheffield.
1879. *Chesterman, W. Belmayne, Sheffield.
1911. *Chick, Miss H., D.Sc. Chestergate, Park-hill, Ealing, W.
1908. ‡Chill, Edwin, M.D. Westleigh, Mattock-road, Ealing, W.
1883. ‡Chinery, Edward F., J.P. Lymington.
1894. ‡CHISHOLM, G. G., M.A., B.Sc., F.R.G.S. (Pres. E, 1907.) 12 Hallhead-road, Edinburgh.
1899. §Chitty, Edward. Sonnenberg, Castle-avenue, Dover.
1899. ‡Chitty, Mrs. Edward. Sonnenberg, Castle-avenue, Dover.
1904. §Chivers, John, J.P. Wychfield, Cambridge.
1882. ‡Chorley, George. Midhurst, Sussex.
1909. ‡Chow, H. H., M.D. 263 Broadway, Winnipeg, Canada.
1893. *CHREE, CHARLES, D.Sc., F.R.S. Kew Observatory, Richmond, Surrey.
1913. §Christie, Dr. M. G. Post Office House, Leeds.
1900. *Christie, R. J. Duke-street, Toronto, Canada.
1875. *Christopher, George, F.C.S. Thorncroft, Chislehurst.
1870. §CHURCH, Sir ARTHUR, K.C.V.O., M.A., F.R.S., F.S.A. Shelsley, Ennerdale-road, Kew.
1903. ‡Clapham, J. H., M.A. King's College, Cambridge.
1901. §Clark, Archibald B., M.A., Professor of Political Economy in the University of Manitoba, Winnipeg, Canada.
1905. *Clark, Cumberland, F.R.G.S. 22 Kensington Park-gardens, W.
1907. *Clark, Mrs. Cumberland. 22 Kensington Park-gardens, W.
1877. *Clark, F. J., J.P., F.L.S. Netherleigh, Street, Somerset.
1902. ‡Clark, G. M. South African Museum, Cape Town.
1908. ‡Clark, James, B.Sc., Ph.D. Newtown School, Waterford, Ireland.
1881. *Clark, J. Edmund, B.A., B.Sc. Asgarth, Riddlesdown-road, Purley, Surrey.
1909. §Clark, J. M., M.A., K.C. The Kent Building, 156 Yonge-street, Toronto, Canada.
1908. §Clark, John R. W. Brothock Bank House, Arbroath, Scotland.
1901. *Clark, Robert M., B.Sc., F.L.S. 27 Albyn-place, Aberdeen.
1907. *Clarke, E. Russell. 11 King's Bench-walk, Temple, E.C.
1902. *CLARKE, Miss LILIAN J., B.Sc., F.L.S. Chartfield Cottage, Brasted Chart, Kent.
1889. *CLAYDEN, A. W., M.A., F.G.S. 5 The Crescent, Mount Radford, Exeter.

Year of
Election.

1908. *Clayton, Miss Edith M. Brackendene, Horsell, Surrey.
1909. §Cleeves, Frederick, F.Z.S. 23 Lime-street, E.C.
1909. ‡Cleeves, W. B. Public Works Department, Government-buildings, Pretoria.
1861. ‡CLELAND, JOHN, M.D., D.Sc., F.R.S. Drumclog, Crewkerne, Somerset.
1905. §Cleland, Mrs. Drumclog, Crewkerne, Somerset.
1905. §Cleland, Lieutenant J. R. Drumclog, Crewkerne, Somerset.
1902. ‡Clements, Olaf P. Tana, St. Bernard's-road, Olton, Warwick.
1904. §CLERK, Dr. DUGALD, F.R.S., M.Inst.C.E. (Pres. G, 1908; Council 1912– .) 57 and 58 Lincoln's Inn Fields, W.C.
1909. ‡Cleve, Miss E. K. P. 74 Kensington Gardens-square, W.
1861. *CLIFTON, R. BELLAMY, M.A., F.R.S., F.R.A.S., Professor of Experimental Philosophy in the University of Oxford. 3 Bardwell-road, Banbury-road, Oxford.
1906. §CLOSE, Colonel C. F., R.E., C.M.G., F.R.G.S. (Pres. E, 1911; Council, 1908–12.) Army and Navy Club, Pall Mall, S.W.
1883. *CLOWES, FRANK, D.Sc., F.C.S. (Local Sec. 1893.) The Grange, College-road, Dulwich, S.E.
1914. §Clowes, Mrs. The Grange, College-road, Dulwich, S.E.
1912. §Clubb, Joseph A., D.Sc. Free Public Museum, Liverpool.
1891. *Coates, Henry, F.R.S.E. Balure, Perth.
1884. ‡Cobb, John. Fitzharris, Abingdon.
1911. §Cobbold, E. S., F.G.S. Church Stretton, Shropshire.
1908. *Cochrane, Miss Constance. The Downs, St. Neots.
1908. ‡Cochrane, Robert, I.S.O., LL.D., F.S.A. 17 Highfield-road, Dublin.
1901. ‡Cockburn, Sir John, K.C.M.G., M.D. 10 Gatestone-road, Upper Norwood, S.E.
1883. ‡Cockshott, J. J. 24 Queen's-road, Southport.
1913. §Codd, J. Alfred. 7 Tettenhall-road, Wolverhampton.
1861. *Coe, Rev. Charles C., F.R.G.S. Whinsbridge, Grosvenor-road, Bournemouth.
1908. ‡*Coffey, Denis J., M.B. 2 Arkendale-road, Glenageary, Co. Dublin.*
1898. ‡Coffey, George. 5 Harcourt-terrace, Dublin
1881. *COFFIN, WALTER HARRIS, F.C.S. National Liberal Club, S.W.
1896. *Coghill, Percy de G. Sunnyside House, Prince's Park, Liverpool.
1901. *Cohen, R. Waley, B.A. 11 Sussex-square, W.
1906. *Coker, Professor Ernest George, M.A., D.Sc., F.R.S.E. City and Guilds of London Technical College, Finsbury, E.C.
1895. *Colby, William Henry. Carregwen, Aberystwyth.
1893. §COLE, GRENVILLE A. J., F.G.S., Professor of Geology in the Royal College of Science, Dublin.
1913. §COLE, Professor F. J. University College, Reading.
1903. ‡Cole, Otto B. 551 Boylston-street, Boston, U.S.A.
1910. §Cole, Thomas Skelton. Westbury, Endcliffe-crescent, Sheffield.
1897. §COLEMAN, Professor A. P., M.A., Ph.D., F.R.S. (Pres. C, 1910.) 476 Huron-street, Toronto, Canada.
1899. ‡Collard, George. The Gables, Canterbury.
1892. ‡Collet, Miss Clara E. 7 Coleridge-road, N.
1912. ‡Collett, J. M., J.P. Kimsbury House, Gloucester.
1887. ‡COLLIE, J. NORMAN, Ph.D., F.R.S., Professor of Organic Chemistry in the University of London. 16 Campden-grove, W.
1913. §Collinge, Walter E., M.Sc. 8 Newhall-street, Birmingham.
1861. *Collingwood, J. Frederick, F.G.S. 8 Oakley-road, Canonbury, N.
1876. ‡COLLINS, J. H., F.G.S. Crinnis House, Par Station, Cornwall.
1910. *Collins, S. Hoare. 9 Cavendish-place, Newcastle-on-Tyne.

Year of Election.

1902. ‡Collins, T. R. Belfast Royal Academy, Belfast.
1914. §Collum, Mrs. Anna Maria. 18 Northbrook-road, Leeson Park, Dublin.
1892. ‡Colman, Dr. Harold G. 1 Arundel-street, Strand, W.C.
1910. *Colver, Robert, jun. Graham-road, Ranmoor, Sheffield.
1905. *Combs, Rev. Cyril W., M.A. Elverton, Castle-road, Newport, Isle of Wight.
1910. *Compton, Robert Harold, B.A. Gonville and Caius College, Cambridge.
1912. §Conner, Dr. William. Glynfield, Havant, Hants.
1871. *Connor, Charles C. 10 College-gardens, Belfast.
1902. ‡Conway, A. W. 100 Leinster-road, Rathmines, Dublin.
1903. ‡Conway, R. Seymour, Litt.D., Professor of Latin in Owens College, Manchester.
1898. §Cook, Ernest H., D.Sc. 27 Berkeley-square, Clifton, Bristol.
1913. §Cook, Gilbert, M.Sc., Assoc.M.Inst.C.E. Engineering Department, The University, Manchester.
1876. *Cooke, Conrad W. The Pines, Langland-gardens, Hampstead, N.W.
1911. ‡Cooke, J. H. 101 Victoria-road North, Southsea.
1888. ‡Cooley, George Parkin. Constitutional Club, Nottingham.
1899. *Coomaraswamy, A. K., D.Sc., F.L.S., F.G.S. Broad Campden, Gloucestershire.
1903. §Cooper, Miss A. J. 22 St. John-street, Oxford.
1901. *Cooper, C. Forster, B.A. Trinity College, Cambridge.
1911. §Cooper, W. E. Henwick Lodge, Worcester.
1912. ‡Cooper, W. F. The Laboratory, Rickmansworth-road, Watford.
1907. ‡Cooper, William. Education Offices, Becket-street, Derby
1904. *Copeman, S. Monckton, M.D., F.R.S. Local Government Board, Whitehall, S.W.
1909. §Copland, Mrs. A. J. Gleniffer, 50 Woodberry Down, N.
1904. *Copland, Miss Louisa. 10 Wynnstay-gardens, Kensington, W.
1909. §Corbett, W. A. 207 Bank of Nova Scotia-building, Winnipeg, Canada.
1887. *Corcoran, Bryan. 23 Croham Park-avenue, South Croydon.
1894. §Corcoran, Miss Jessie R. Rotherfield Cottage, Bexhill-on-Sea.
1901. *Cormack, J. D., D.Sc., Professor of Civil Engineering and Mechanics in the University of Glasgow.
1893. *Corner, Samuel, B.A., B.Sc. Abbotsford House, Waverley-street, Nottingham.
1889. ‡Cornish, Vaughan, D.Sc., F.R.G.S. Woodville, Camberley.
1884. *Cornwallis, F. S. W., F.L.S. Linton Park, Maidstone.
1900. §Cortie, Rev. A. L., S.J., F.R.A.S. Stonyhurst College, Blackburn.
1905. ‡Cory, Professor G. E., M.A. Rhodes University College, Grahamstown, Cape Colony.
1909. *Cossar, G. C., M.A., F.G.S. Southview, Murrayfield, Edinburgh.
1910. §Cossar, James. 53 Belford-road, Edinburgh.
1911. ‡Cossey, Miss, M.A. High School for Girls, Kent-road, Southsea.
1908. *Costello, John Francis, B.A. The Rectory, Ballymackey, Nenagh Ireland.
1874. *Cotterill, J. H., M.A., F.R.S. Hillcrest, Parkstone, Dorset.
1908. ‡Cotton, Alderman W. F., D.L., J.P., M.P. Hollywood, Co. Dublin.
1908. ‡Courtenay, Colonel Arthur H., C.B., D.L. United Service Club, Dublin.
1896. ‡Courtney, Right Hon. Lord. (Pres. F, 1896.) 15 Cheyne-walk, Chelsea, S.W.
1911. ‡Couzens, Sir G. E., K.L.H. Glenthorne, Kingston-crescent, Portsmouth.

Year of Election.

1908. ‡Cowan, P. C., B.Sc., M.Inst.C.E. 33 Ailesbury-road, Dublin.
1872. *Cowan, Thomas William, F.L.S., F.G.S. Upcott House, Taunton, Somersetshire.
1903. ‡Coward, H. Knowle Board School, Bristol.
1900. §Cowburn, Henry. Dingle Head, Leigh, Lancashire.
1895. *Cowell, Philip H., M.A., D.Sc., F.R.S. 62 Shooters Hill-road, Blackheath, S.E.
1899. ‡Cowper-Coles, Sherard. 1 and 2 Old Pye-street, Westminster, S.W.
1913. §Cox, A. Hubert. King's College, Strand, W.C.
1909. ‡Cox, F. J. C. Anderson-avenue, Winnipeg, Canada.
1906. ‡*Cox, S. Herbert, Professor of Mining in the Imperial College of Science and Technology, S.W.*
1905. ‡Cox, W. H. Royal Observatory, Cape Town.
1912. ‡Craig, D. D., M.A., B.Sc., M.B. The University, St. Andrews, N.B.
1908. ‡Craig, James, M.D. 18 Merrion-square North, Dublin.
1911. §Craig, J. I. Homelands, Park-avenue, Worthing.
1884. §Craigie, Major P. G., C.B., F.S.S. (Pres. F, 1900; Council, 1908- .) Bronté House, Lympstone, Devon.
1906. ‡Craik, Sir Henry, K.C.B., LL.D., M.P. 5a Dean's-yard, Westminster, S.W.
1908. *Cramer, W., Ph.D., D.Sc. Physiological Department, The University, Edinburgh.
1906. ‡*Cramp, William. Redthorn, Whalley-road, Manchester.*
1905. *Cranswick, W. F. P.O. Box 65, Bulawayo, Rhodesia.
1906. ‡Craven, Henry. (Local Sec. 1906.) Greenbank, West Lawn, Sunderland.
1905. ‡Crawford, Mrs. A. M. Marchmont, Rosebank, near Cape Town.
1910. *Crawford, O. G. S. The Grove, East Woodhay, Newbury.
1905. ‡Crawford, Professor Lawrence, M.A., D.Sc., F.R.S.E. South African College, Cape Town.
1871. *Crawford, William Caldwell, M.A. 1 Lockharton-gardens, Colinton-road, Edinburgh.
1905. ‡Crawford, W. C., jun. 1 Lockharton-gardens, Colinton-road, Edinburgh.
1890. §Crawshaw, Charles B. Rufford Lodge, Dewsbury.
1883. *Crawshaw, Edward. F.R.G.S. 25 Tollington-park, N.
1885. §Creak, Captain E. W., C.B., R.N., F.R.S. (Pres. E, 190 ; Council, 1896–1903.) 9 Hervey-road, Blackheath, S.E.
1876. *Crewdson, Rev. Canon George. Whitstead, Barton-road, Cambridge.
1887. *Crewdson, Theodore. Spurs, Styall, Handforth, Manchester.
1911. ‡Crick, George C., F.G.S. British Museum (Natural History), S.W.
1904 ‡Crilly, David. 7 Well-street, Paisley.
1880. *Crisp, Sir Frank, Bart., B.A., LL.B., F.L.S., F.G.S. 5 Lansdowne-road, Notting Hill, W.
1908. §Crocker, J. Meadmore. Albion House, Bingley, Yorkshire.
1905. §Croft, Miss Mary. Quedley, Shottermill.
1890. *Croft, W. B., M.A. Winchester College, Hampshire.
1878. *Croke, John O'Byrne, M.A. Clouneagh, Ballingarry-Lacy, Co. Limerick.
1913. §Crombie, J. E. Parkhill House, Dyce, Aberdeenshire.
1903. *Crompton, Holland. Oaklyn, Cross Oak-road, Berkhamsted.
1901. ‡Crompton, Colonel R. E., C.B., M.Inst.C.E. (Pres. G, 1901.) Kensington-court, W.
1887. ‡Crook, Henry T., M.Inst.C.E Lancaster-avenue, Manchester.

Year of Election.

1898. §Crooke, William, B.A. (Pres. H, 1910 ; Council, 1910– .) Langton House, Charlton Kings, Cheltenham.
1865. §Crookes, Sir William, O.M., D.Sc., Pres.R.S., V.P.C.S. (President, 1898 ; Pres. B, 1886 ; Council, 1885–91.) 7 Kensington Park-gardens, W.
1879. ‡Crookes, Lady. 7 Kensington Park-gardens, W.
1897. *Crookshank, E. M., M.B. Saint Hill, East Grinstead, Sussex.
1909. ‡Crosby, Rev. E. H. Lewis, B.D. 36 Rutland-square, Dublin.
1905. ‡Crosfield, Hugh T. Walden, Coombe-road, Croydon.
1894. *Crosfield, Miss Margaret C. Undercroft, Reigate.
1904. §Cross, Professor Charles R. Massachusetts Institute of Technology, Boston, U.S.A.
1890. ‡*Cross, E. Richard, LL.B. Harwood House, New Parks crescent, Scarborough.*
1905. §Cross, Robert. 13 Moray-place, Edinburgh.
1904. *Crossley, A. W., D.Sc., Ph.D., F.R.S., Professor of Chemistry to the Pharmaceutical Society of Great Britain. 10 Crediton-road, West Hampstead, N.W.
1908. ‡Crossley, F. W. 30 Molesworth-street, Dublin.
1897. *Crosweller, Mrs. W. T. Kent Lodge, Sidcup, Kent.
1890. *Crowley, Ralph Henry, M.D. Sollershott W., Letchworth.
1910. §Crowther, Dr. C., M.A. The University, Leeds.
1910. *Crowther, James Arnold. St. John's College, Cambridge.
1911. §Crush, S. T. Care of Messrs. Yarrow & Co., Ltd., Scotstoun West, Glasgow.
1883. *Culverwell, Edward P., M.A., Professor of Education in Trinity College, Dublin.
1883. ‡Culverwell, T. J. H. Litfield House, Clifton, Bristol.
1911. §Cumming, Alexander Charles, D.Sc. Chemistry Department, University of Edinburgh.
1911. §Cummins, Major H. A., M.D., C.M.G., Professor of Botany in University College, Cork.
1898. ‡Cundall, J. Tudor. 1 Dean Park-crescent, Edinburgh.
1861. *Cunliffe, Edward Thomas. The Parsonage, Handforth, Manchester.
1861. *Cunliffe, Peter Gibson. Dunedin, Handforth, Manchester.
1905. ‡Cunningham, Miss A. 2 St. Paul's-road, Cambridge.
1882. *Cunningham, Lieut.-Colonel Allan, R.E., A.I.C.E. 20 Essex-villas, Kensington, W.
1905. ‡Cunningham, Andrew. Earlsferry, Campground-road, Mowbray, South Africa.
1911. ‡Cunningham, E. St. John's College, Cambridge.
1885. ‡Cunningham, J. T., B.A. Biological Laboratory, Plymouth.
1869. ‡Cunningham, Robert O., M.D., F.L.S., Professor of Natural History in Queen's College, Belfast.
1883. *Cunningham, Ven. W., D.D., D.Sc. (Pres. F, 1891, 1905.) Trinity College, Cambridge.
1892. ‡*Cunningham-Craig, E. H., B.A., F.G.S.* 14a *Dublin-street, Edinburgh.*
1900. *Cunnington, William A., M.A., Ph.D., F.Z.S. 25 Orlando-road, Clapham Common, S.W.
1912. §Cunynghame, Sir Henry H., K.C.B. (Pres. F, 1912.) 15 The Leas, Folkestone.
1913. §Currall, A. E. Streetsbrook-road, Solihull, Birmingham.
1908. ‡Currelly, C. T., M.A., F.R G.S. United Empire Club, 117 Piccadilly, W.
1892. *Currie, James, M.A., F.R.S.E. Larkfield, Wardie-road, Edinburgh.
1905. ‡Currie, Dr. O. J. Manor House, Mowbray, Cape Town.

Year of Election.

1905. ‡Currie, W. P. P.O. Box 2010, Johannesburg.
1902. ‡Curry, Professor M., M.Inst.C.E. 5 King's-gardens, Hove.
1912. §Curtis, Charles. Field House, Cainscross, Stroud, Gloucestershire.
1907. ‡CUSHNY, ARTHUR R., M.D., F.R.S., Professor of Pharmacology in University College, Gower-street, W.C.
1913. §Cutler, A. E. 5 Charlotte-road, Edgbaston, Birmingham.
1913. §Czaplicka, Miss M. A. Somerford College, Oxford.

1910. §Dakin, Dr. W. J., Professor of Biology in the University of Western Australia, Perth, Western Australia.
1914. §Dakin, Mrs. University of Western Australia, Perth, Western Australia.
1898. *DALBY, W. E., M.A., B.Sc., F.R.S., M.Inst.C.E. (Pres. G, 1910), Professor of Civil and Mechanical Engineering in the City and Guilds of London Institute, Exhibition-road, S.W.
1889. *Dale, Miss Elizabeth. Garth Cottage, Oxford-road, Cambridge.
1906. §Dale, William, F.S.A., F.G.S. The Lawn, Archer's-road, Southampton.
1907. ‡DALGLIESH, RICHARD, J.P., D.L. Ashfordby Place, near Melton Mowbray.
1904. *DALTON, J. H. C., M.D. The Plot, Adams-road, Cambridge.
1862. ‡DANBY, T. W., M.A., F.G.S. The Crouch, Seaford, Sussex.
1905. ‡Daniel, Miss A. M. 3 St. John's-terrace, Weston-super-Mare.
1901. *DANIELL, G. F., B.Sc. Woodberry, Oakleigh Park, N.
1896. §Danson, F. C. Tower-buildings, Water-street, Liverpool.
1897. ‡Darbishire, F. V., B.A., Ph.D. Dorotheenstrasse 12, Dresden 20.
1903. §DARBISHIRE, Dr. OTTO V. The University, Bristol.
1905. ‡Darwin, Lady. Newnham Grange, Cambridge.
1904. *Darwin, Charles Galton. Newnham Grange, Cambridge.
1899. *Darwin, Erasmus. The Orchard, Huntingdon-road, Cambridge.
1882. *DARWIN, Sir FRANCIS, M.A., M.B., LL.D., D.Sc., F.R.S., F.L.S. (PRESIDENT, 1908; Pres. D, 1891; Pres. K, 1904; Council, 1882–84, 1897–1901.) 10 Madingley-road, Cambridge.
1878. *DARWIN, HORACE, M.A., F.R.S. The Orchard, Huntingdon-road, Cambridge.
1894. *DARWIN, Major LEONARD, F.R.G.S. (Pres. E, 1896; Council, 1899–1905.) 12 Egerton-place, South Kensington, S.W.
1882. ‡Darwin, W. E., B.A., F.G.S. 11 Egerton-place, S.W.
1910. ‡Dauncey, Mrs Thursby. Lady Stewert, Heath-road, Weybridge.
1908. ‡*Davey, H. 15 Victoria-road, Brighton.*
1880. *DAVEY, HENRY, M.Inst.C.E. Conaways, Ewell, Surrey.
1884. ‡David, A. J., B.A., LL.B. 4 Harcourt-buildings, Temple, E.C.
1904. ‡Davidge, H. T., B.Sc., Professor of Electricity in the Ordnance College, Woolwich.
1913. §Davidge, W. R., A.M.Inst.C.E. Bank House, Lewisham, S.E.
1913. §Davidge, Mrs. Bank House, Lewisham, S.E.
1909. ‡Davidson, A. R. 150 Stradbrooke-place, Winnipeg, Canada.
1912. ‡Davidson, Rev. J. The Manse, Douglas, Isle of Man.
1912. ‡Davidson, John, M.A., D.Ph. Training College, Small's Wynd, Dundee.
1902. *Davidson, S. C. Seacourt, Bangor, Co. Down.
1910. *Davie, Robert C., M.A., B.Sc. Royal Botanic Garden, Edinburgh.
1887. *Davies, H. Rees. Treborth, Bangor, North Wales.
1904. §Davies, Henry N., F.G.S. St. Chad's, Weston-super-Mare.
1906. ‡Davies, S. H. Ryecroft, New Earswick, York.
1893. *Davies, Rev. T. Witton, B.A., Ph.D., D.D., Professor of Semitic Languages in University College, Bangor, North Wales.

Year of Election.

1896. *Davies, Thomas Wilberforce, F.G.S. 41 Park-place, Cardiff.
1870. *Davis, A. S. St. George's School, Roundhay, near Leeds.
1873. *Davis, Alfred. 37 Ladbroke-grove, W.
1896. *Davis, John Henry Grant. Dolobran, Wood Green, Wednesbury.
1910. ‡Davis, John King. 2 Brockenhurst Green-street, Jersey.
1905. §Davis, Luther. P.O. Box 898, Johannesburg.
1885. *Davis, Rev. Rudolf. Mornington, Elmbridge-road. Gloucester.
1905. ‡DAVY, JOSEPH BURTT, F.R.G.S., F.L.S. Care of Messrs. Dulau & Co., 37 Soho-square, W.
1912. §Dawkins, Miss Ella Boyd. Fallowfield House, Fallowfield, Manchester.
1864. ‡DAWKINS, W. BOYD, D.Sc., F.R.S., F.S.A., F.G.S. (Pres. C, 1888; Council, 1882–88.) Fallowfield House, Fallowfield, Manchester.
1885. *Dawson, Lieut.-Colonel H. P., R.A. Hartlington Hall, Burnsall, Skipton-in-Craven.
1901. *Dawson, P. The Acre, Maryhill, Glasgow.
1905. ‡Dawson, Mrs. The Acre. Maryhill, Glasgow.
1912. *Dawson, Shepherd, M.A., B.Sc. Drumchapel, near Glasgow.
1906. §Dawson, William Clarke. Whitefriargate, Hull.
1859. *Dawson, Captain W. G. Abbots Morton, near Worcester.
1900. ‡Deacon, M. Whittington House, near Chesterfield.
1909. §Dean, George, F.R.G.S. 5 Wordsworth-mansions, Queen's Club-gardens, W.
1901. *Deasy, Captain H. H. P. Cavalry Club, 127 Piccadilly, W.
1884. *Debenham, Frank, F.S.S. 1 Fitzjohn's-avenue, N.W.
1866. ‡DEBUS, HEINRICH, Ph.D., F.R.S., F.C.S. (Pres. B, 1869; Council, 1870–75.) 4 Schlangenweg, Cassel, Hessen.
1893. *Deeley, R. M., M.Inst.C.E., F.G.S. Abbeyfield, Salisbury-avenue, Harpenden, Herts.
1911. ‡Delahunt, C. G. The Municipal College, Portsmouth.
1878. ‡DELANY, Very Rev. WILLIAM, LL.D. University College, Dublin.
1908. *Delf, Miss E. M. Westfield College, Hampstead, N.W.
1907. ‡*De Lisle, Mrs. Edwin. Charnwood Lodge, Coalville, Leicestershire.*
1896. ‡Dempster, John. Tynron, Noctorum, Birkenhead.
1902. *DENDY, ARTHUR, D.Sc., F.R.S., F.L.S. (Council, 1912–), Professor of Zoology in King's College, London, W.C.
1913. *Denman, Thomas Hercy. 17 Churchgate, Retford, Nottinghamshire.
1908. ‡Dennehy, W. F. 23 Leeson-park, Dublin.
1889. §DENNY, ALFRED, M.Sc., F.L.S., Professor of Biology in the University of Sheffield.
1909. §Dent, Edward, M.A. 2 Carlos-place, W.
1874. *Derham, Walter, M.A., LL.M., F.G.S. Junior Carlton Club, Pall Mall, S.W.
1907. *Desch, Cecil H., D.Sc., Ph.D. 3 Kelvinside-terrace North, Glasgow.
1908. ‡Despard, Miss Kathleen M. 6 Sutton Court-mansions, Grove Park-terrace, Chiswick, W.
1894. *Deverell, F. H. 7 Grote's-place, Blackheath, S.E.
1868. *DEWAR, Sir JAMES, M.A., LL.D., D.Sc., F.R.S., F.R.S.E., V.P.C.S., Fullerian Professor of Chemistry in the Royal Institution, London, and Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge. (PRESIDENT, 1902; Pres. B, 1879; Council, 1883–88.) 1 Scroope-terrace, Cambridge.
1881. ‡Dewar, Lady. 1 Scroope-terrace, Cambridge.
1884. *Dewar, William, M.A. Horton House, Rugby.
1908. §Dicks, Henry. Haslecourt, Horsell, Woking.

Year of Election.

1904. ‡Dickson, Right Hon. Charles Scott, K.C., LL.D., M.P. Carlton Club, Pall Mall, S.W.
1881. ‡Dickson, Edmund, M.A., F.G.S. Claughton House, Garstang, R.S.O., Lancashire.
1887. §DICKSON, H. N., D.Sc., F.R.S.E., F.R.G.S. (Pres. E, 1913), Professor of Geography in University College, Reading. 160 Castle-hill, Reading.
1902. §Dickson, James D. Hamilton, M.A., F.R.S.E. 6 Cranmer-road, Cambridge.
1913. *Dickson, T. W. 60 Jeffrey's-road, Clapham, S.W.
1877. ‡Dillon, James, M.Inst.C.E. 36 Dawson-street, Dublin.
1908. ‡Dines, J. S. Pyrton Hill, Watlington.
1901. §Dines, W. H., B.A., F.R.S. Pyrton Hill, Watlington.
1905. §DIXEY, F. A., M.A., M.D., F.R.S. (Council, 1913– .) Wadham College, Oxford.
1899. *DIXON, A. C., D.Sc., F.R.S., Professor of Mathematics in Queen's University, Belfast. Hurstwood, Malone Park, Belfast.
1874. *DIXON, A. E., M.D., Professor of Chemistry in University College, Cork.
1900. ‡Dixon, A. Francis, Sc.D., Professor of Anatomy in the University of Dublin.
1905. ‡Dixon, Miss E. K. Fern Bank, St. Bees, Cumberland.
1908. ‡Dixon, Edward K., M.E., M.Inst.C.E. Castlebar, Co. Mayo.
1888. ‡Dixon, Edward T. Racketts, Hythe, Hampshire.
1908. *DIXON, ERNEST, B.Sc., F.G.S. The Museum, Jermyn-street, S.W.
1900. *Dixon, Lieut.-Colonel George, M.A. Fern Bank, St. Bees, Cumberland.
1879. *DIXON, HAROLD B., M.A., F.R.S., F.C.S. (Pres. B, 1894; Council 1913–), Professor of Chemistry in the Victoria University, Manchester.
1914. §Dixon, Mrs. H. B., Beechey House, Wilbraham-road, Fallowfield, Manchester.
1902. ‡DIXON, HENRY H., D.Sc., F.R.S., Professor of Botany in the University of Dublin. Clevedon, Temple-road, Dublin.
1913. §Dixon, S. M., M.A., M.Inst.C.E., Professor of Civil Engineering in the Imperial College of Science and Technology, London, S.W.
1908. *Dixon, Walter, F.R.M.S. Derwent, 30 Kelvinside-gardens, Glasgow.
1907. *DIXON, Professor WALTER E., F.R.S. The Museums, Cambridge.
1902. ‡*Dixon, W. V. Scotch Quarter, Carrickfergus.*
1896. §Dixon-Nuttall, F. R. Ingleholme, Eccleston Park, Prescot.
1890. ‡Dobbie, James J., D.Sc., LL.D., F.R.S., Principal of the Government Laboratories, 13 Clement's Inn-passage, W.C.
1885. §Dobbin, Leonard, Ph.D. The University, Edinburgh.
1860. *Dobbs, Archibald Edward, M.A., J.P., D.L. Castle Dobbs, Carrickfergus, Co. Antrim.
1902. ‡Dobbs, F. W., M.A. Eton College, Windsor.
1908. ‡DODD, Hon. Mr. Justice. 26 Fitzwilliam-square, Dublin.
1876. ‡Dodds, J. M. St. Peter's College, Cambridge.
1912. §Don, A. W. R. The Lodge, Broughty Ferry, Forfarshire.
1912. ‡Don, Alexander, M.A., F.R.C.S. Park House, Nethergate, Dundee.
1912. ‡Don, Robert Bogle, M.A. The Lodge, Broughty Ferry, Forfarshire.
1904. ‡Doncaster, Leonard, M.A. Museum of Zoology, Cambridge.
1896. ‡Donnan, F. E. Ardenmore-terrace, Holywood, Ireland.
1901. ‡Donnan, F. G., M.A., Ph.D., F.R.S., Professor of Chemistry in University College, Gower-street, W.C.
1905. ‡*Donner, Arthur. Helsingfors, Finland.*

Year of Election.

1905. §Dornan, Rev. S. S. P.O. Box 510, Bulawayo, South Rhodesia, South Africa.
1863. *Doughty, Charles Montagu. 26 Grange-road, Eastbourne.
1909. ‡Douglas, A. J., M.D. City Health Department, Winnipeg, Canada.
1909. *Douglas, James. 99 John-street, New York, U.S.A.
1912. ‡Doune, Lord. Kinfauns Castle, Perth.
1903. ‡*Dow, Miss Agnes R. 81 Park-mansions, Knightsbridge, S.W.*
1884. *Dowling, D. J. Sycamore, Clive-avenue, Hastings.
1865. *Dowson, E. Theodore, F.R.M.S. Geldeston, near Beccles, Suffolk.
1881. *Dowson, J. Emerson, M.Inst.C.E. Landhurst Wood, Hartfield, Sussex.
1913. §Dracopoli, J. N. Pollard's Wood Grange, Chalfont St. Giles, Buckinghamshire.
1892. *Dreghorn, David, J.P. Greenwood, Pollokshields, Glasgow.
1912. §Drever, James, M.A., B.Sc. 32 Lomond-road, Trinity, Edinburgh.
1905. ‡Drew, H. W., M.B., M.R.C.S. Mocollup Castle, Ballyduff, S.O., Co. Waterford.
1906. *Drew, Joseph Webster, M.A., LL.M. Hatherley Court, Cheltenham.
1906. *Drew, Mrs. Hatherley Court, Cheltenham.
1908. ‡Droop, J. P. 11 Cleveland-gardens, Hyde Park, W.
1893. §DRUCE, G. CLARIDGE, M.A., F.L.S. (Local Sec. 1894.) Yardley Lodge, 9 Crick-road, Oxford.
1909. *Drugman, Julien, Ph.D., M.Sc. 117 Rue Gachard, Brussels.
1907. §Drysdale, Charles V., D.Sc. Queen Anne's-chambers, S.W.
1892. ‡Du Bois, Professor Dr. H. Herwarthstrasse 4, Berlin, N.W.
1856. *DUCIE, The Right Hon. HENRY JOHN REYNOLDS MORETON, Earl of, G.C.V.O., F.R.S., F.G.S. 16 Portman-square, W.
1870. ‡Duckworth, Henry, F.L.S., F.G.S. 7 Grey Friars, Chester.
1900. *Duckworth, W. L. H., M.D., Sc.D. Jesus College, Cambridge.
1895. *Duddell, William, F.R.S. 47 Hans-place, S.W.
1912. §Duffield, Francis A., M.B. Holmleigh, Manor-road, Sutton Coldfield.
1904. *Duffield, Professor W. Geoffrey, D.Sc. University College, Reading.
1890. ‡Dufton, S. F. Trinity College, Cambridge.
1899. *Dugdale-Bradley, J. W., M.Inst.C.E. Westminster City Hall, Charing Cross-road, W.C.
1911. ‡Dummer, John. 85 Cottage-grove, Southsea.
1909. ‡Duncan, D. M., M.A. 83 Spence-street, Winnipeg, Canada.
1891. *Duncan, Sir John, J.P. 'South Wales Daily News' Office, Cardiff.
1913. §Dunlop, Dr. Andrew. Belgrave House, St. Helier, Jersey.
1910. ‡Dunn, Rev. J. Road Hill Vicarage, Bath.
1876. ‡Dunnachie, James. 48 West Regent-street, Glasgow.
1884. §Dunnington, Professor F. P. University of Virginia, Charlottesville, Virginia, U.S.A.
1893. *Dunstan, M. J. R., Principal of the South-Eastern Agricultural College, Wye, Kent.
1891. ‡Dunstan, Mrs. South-Eastern Agricultural College, Wye, Kent.
1885. *DUNSTAN, WYNDHAM R., C.M.G., M.A., LL.D., F.R.S., F.C.S. (Pres. B, 1906; Council, 1905–08), Director of the Imperial Institute, S.W.
1911. ‡Dupree, Colonel Sir W. T. Craneswater, Southsea.
1913. §Durie, William. Sunnyside, Beechwood-avenue, Finchley, N.
1905. §Dutton, C. L. O'Brien. High Commissioner's Office, Pretoria.
1910. §Dutton, F. V., B.Sc. County Agricultural Laboratories, Richmond-road, Exeter.
1895. *DWERRYHOUSE, ARTHUR R., D.Sc., F.G.S. Deraness, Deramore Park, Belfast.

Year of Election.

1911. ‡Dye, Charles. Woodcrofts, London-road, Portsmouth.
1885. *Dyer, Henry, M.A., D.Sc., LL.D. 8 Highburgh-terrace, Dowanhill, Glasgow.
1895. §Dymond, Thomas S., F.C.S. Savile Club, Piccadilly, W.
1905. *Dyson, F. W., M.A., F.R.S. (Council, 1905–11), Astronomer Royal, Royal Observatory, Greenwich, S.E.
1910. ‡Dyson, W. H. Maltby Colliery, near Rotherham, Yorkshire.

1912. ‡Earland, Arthur, F.R.M.S. 34 Granville-road, Watford.
1899. ‡East, W. H. Municipal School of Art, Science, and Technology, Dover.
1909. *Easterbrook, C. C., M.A., M.D. Crichton Royal Institution, Dumfries.
1893. *Ebbs, Alfred B. Northumberland-alley, Fenchurch-street, E.C.
1906. *Ebbs, Mrs. A. B. Tuborg, Plaistow-lane, Bromley, Kent.
1909. ‡Eccles, J. R. Gresham's School, Holt, Norfolk.
1903. *Eccles, W. H., D.Sc. 26, Ridgmount-gardens Gower-street, W.C.
1908. *Eddington, A. S., M.A., M.Sc., Plumian Professor of Astronomy and Experimental Philosophy in the University of Cambridge. Trinity College, Cambridge.
1870. *Eddison, John Edwin, M.D., M.R.C.S. The Lodge, Adel, Leeds.
1858. *Eddy, James Ray, F.G.S. The Grange, Carleton, Skipton.
1911. *Edge, S. F. 14 New Burlington-street, W.
1911. *Edgell, Miss Beatrice. Bedford College, Baker-street, W.
1884. *Edgell, Rev. R. Arnold, M.A. Beckley Rectory, East Sussex.
1887. §Edgeworth, F. Y., M.A., D.C.L., F.S.S. (Pres. F, 1889; Council, 1879–86, 1891–98), Professor of Political Economy in the University of Oxford. All Souls College, Oxford.
1870. *Edmonds, F. B. 6 Clement's Inn, W.C.
1883. ‡Edmonds, William. Wiscombe Park, Colyton, Devon.
1888. *Edmunds, Henry. Antron, 71 Upper Tulse-hill, S.W.
1901. *Edridge-Green, F. W., M.D., F.R.C.S. 99 Walm-lane, Willesden Green, N.W.
1899. §Edwards, E. J., Assoc.M.Inst.C.E. 24 West Side, Wandsworth Common, S.W.
1913. §Edwards, E. J. University College, Cardiff.
1903. ‡Edwards, Mrs. Emily. Norley Grange, 73 Leyland-road, Southport.
1903. ‡Edwards, Francis. Norley Grange, 73 Leyland-road, Southport.
1903. ‡Edwards, Miss Marion K. Norley Grange, 73 Leyland-road, Southport.
1901. ‡Eggar, W. D. Eton College, Windsor.
1909. ‡Eggertson, Arni. 120 Emily-street, Winnipeg, Canada.
1909. §Ehrenborg, G. B. 63 Fairfield-building, Vancouver, B.C., Canada.
1907. *Elderton, W. Palin. 74 Mount Nod-road, Streatham, S.W.
1890. ‡Elford, Percy. 115 Woodstock-road, Oxford.
1913. §Elkington, Herbert F. Clunes, Wentworth-road, Sutton Coldfield.
1901. *Elles, Miss Gertrude L., D.Sc. Newnham College, Cambridge.
1904. ‡Elliot, Miss Agnes I. M. Newnham College, Cambridge.
1904 ‡Elliot, R. H. Clifton Park, Kelso, N.B.
1905. ‡Elliott, C. C., M.D. Church-square, Cape Town.
1883. *Elliott, Edwin Bailey, M.A., F.R.S., F.R.A.S., Waynflete Professor of Pure Mathematics in the University of Oxford. 4 Bardwell-road, Oxford.
Elliott, John Fogg. Elvet Hill, Durham.

Year of Election.

1912. §Elliott, Dr. W. F., F.Z.S. 21 Bennett's-hill, Birmingham.
1906. *Ellis, David, D.Sc., Ph.D. Royal Technical College, Glasgow.
1875. *Ellis, H. D. 12 Gloucester-terrace, Hyde Park, W.
1906. §Ellis, Herbert. 120 Regent-road, Leicester.
1913. §Ellis, Herbert Willoughby, A.M.Inst.C.E. Holly Hill, Berkswell, Warwickshire.
1880. **Ellis, John Henry.* (*Local Sec.* 1883.) 10 *The Crescent, Plymouth.*
1891. §Ellis, Miss M. A. 14 Wellington-square, Oxford.
1906. ‡Elmhirst, Charles E. (Local Sec. 1906.) 29 Mount-vale, York.
1910. §Elmhirst, Richard. Marine Biological Station, Millport.
1911. ‡Elwes, H. J., F.R.S. Colesborne Park, near Cheltenham.
1884. ‡Emery, Albert H. Stamford, Connecticut, U.S.A.
1905. ‡Epps, Mrs. Dunhurst, Petersfield, Hampshire.
1894. ‡Erskine-Murray, J., D.Sc., F.R.S.E. 4 Great Winchester-street, E.C.
1862. *Esson, William, M.A., F.R.S., F.R.A.S., Savilian Professor of Geometry in the University of Oxford. 13 Bradmore-road, Oxford.
1887. *Estcourt, Charles, F.I.C. 5 Seymour-grove, Old Trafford, Manchester.
1887. *Estcourt, P. A., F.C.S., F.I.C. 5 Seymour-grove, Old Trafford, Manchester.
1911. ‡Etherton, G. Hammond. (Local Sec. 1911.) Town Hall, Portsmouth.
1897. *Evans, Lady. Care of Union of London and Smith's Bank, Berkhamsted, Herts.
1889. *Evans, A. H., M.A. 9 Harvey-road, Cambridge.
1905. ‡Evans, Mrs. A. H. 9 Harvey-road, Cambridge.
1870. *Evans, Sir Arthur John, M.A., LL.D., F.R.S., F.S.A. (Pres. H, 1896.) Youlbury, Abingdon.
1908. ‡Evans, Rev. Henry, D.D., Commissioner of National Education, Ireland. Blackrock, Co. Dublin.
1887. *Evans, Mrs. Isabel. Hoghton Hall, Hoghton, near Preston.
1883. *Evans, Mrs. James C. Casewell Lodge, Llanwrtyd Wells, South Wales.
1913. §Evans, J. Jameson. 85 Edmund-street, Birmingham.
1910. *Evans, John W., D.Sc., LL.B., F.G.S. 75 Craven Park-road, Harlesden, N.W.
1885. *Evans, Percy Bagnall. The Spring, Kenilworth.
1905. ‡Evans, R. O. Ll. Broom Hall, Chwilog, R.S.O., Carnarvonshire.
1905. ‡Evans, T. H. 9 Harvey-road, Cambridge.
1910. ‡Evans, T. J. The University, Sheffield.
1865. *Evans, William. The Spring, Kenilworth.
1909. ‡Evans, W. Sanford, M.A. (Local Sec. 1909.) 43 Edmonton-street, Winnipeg.
1903. ‡*Evatt, E. J., M.B.* 8 *Kyveilog-street, Cardiff.*
1902. *Everett, Percy W. Oaklands, Elstree, Hertfordshire.
1883. ‡Eves, Miss Florence. Uxbridge.
1881. ‡Ewart, J. Cossar, M.D., F.R.S. (Pres. D, 1901), Professor of Natural History in the University of Edinburgh.
1874. ‡Ewart, Sir W. Quartus, Bart. (Local Sec. 1874.) Glenmachan, Belfast.
1913. *Ewen, J. T. 104 King's-gate, Aberdeen.
1913. *Ewen, Mrs. J. T. 104 King's-gate, Aberdeen.
1876. *Ewing, Sir James Alfred, K.C.B., M.A., LL.D., F.R.S., F.R.S.E., M.Inst.C.E. (Pres. G, 1906), Director of Naval Education, Admiralty, S.W. Froghole, Edenbridge, Kent.

Year of Election.

1903. §Ewing, Peter, F.L.S. The Frond, Uddingston, Glasgow.
1884. *Eyerman, John, F.Z.S. Oakhurst, Easton, Pennsylvania, U.S.A.
1912. §EYRE, J. VARGAS. South-Eastern Agricultural College, Wye, Kent.
Eyton, Charles. Hendred House, Abingdon.

1906. *Faber, George D. 14 Grosvenor-square, W.
1901. *Fairgrieve, M. McCallum. 37 Queen's-crescent, Edinburgh.
1865. *FAIRLEY, THOMAS, F.R.S.E., F.C.S. 8 Newton-grove, Leeds.
1910. ‡Falconer, J. D. The Limes, Little Berkhamsted, Hertford.
1908. ‡Falconer, Robert A., M.A. 44 Merrion-square, Dublin.
1896. §Falk, Herman John, M.A. Thorshill, West Kirby, Cheshire.
1902. §Fallaize, E. N., B.A. Vinchelez, Chase Court-gardens, Windmill-hill, Enfield.
1907. *Fantham, H. B., D.Sc., B.A. 100 Mawson-road, Cambridge.
1902. ‡Faren, William. 11 Mount Charles, Belfast.
1892. *FARMER, J. BRETLAND, M.A., F.R.S., F.L.S. (Pres. K, 1907; Council, 1912- .) South Park, Gerrards Cross.
1897. *Farnworth, Mrs. Ernest. Broadlands, Goldthorn Hill, Wolverhampton.
1904. ‡Farnworth, Miss Olive. Broadlands, Goldthorn Hill, Wolverhampton.
1885. **Farquharson, Mrs. R. F. O. Tillydrine, Kincardine O'Neil, N.B.*
1905. ‡Farrar, Edward. P.O. Box 1242, Johannesburg.
1913. §Farrow, F. D. The University, Liverpool.
1903. §Faulkner, Joseph M. 17 Great Ducie-street, Strangeways, Manchester.
1913. §Fawcett, C. B. Hartley University, Southampton.
1890. *Fawcett, F. B. 1 Rockleaze-avenue, Sneyd Park, Bristol.
1906. §Fawcett, Henry Hargreave. Thorncombe, near Chard, Somerset.
1900. ‡FAWCETT, J. E., J.P. (Local Sec. 1900.) Low Royd, Apperley Bridge, Bradford.
1902. *Fawsitt, C. E., Ph.D., Professor of Chemistry in the University of Sydney, New South Wales.
1911. *Fay, Mrs. A. Q. Chedworth, Rustat-road, Cambridge.
1909. *Fay, Charles Ryle, M.A. Christ's College, Cambridge.
1906. *Fearnsides, Edwin G., M.A., M.B., B.Sc., London Hospital, E.
1901. *FEARNSIDES, W. G., M.A., F.G.S. Sorby Professor of Geology in the University of Sheffield. 10 Silver Birch-avenue, Fulwood, Sheffield.
1910. *Fearnsides, Mrs. 10 Silver Birch-avenue, Fulwood, Sheffield.
1905. §Feilden, Colonel H. W., C.B., F.R.G.S., F.G.S. Burwash, Sussex.
1900. *Fennell, William John. Deramore Drive, Belfast.
1904. ‡Fenton, H. J. H., M.A., F.R.S. 19 Brookside, Cambridge.
1871. *FERGUSON, JOHN, M.A., LL.D., F.R.S.E., F.S.A., F.C.S., Professor of Chemistry in the University of Glasgow.
1901. ‡Ferguson, R. W. 16 Linden-road, Bournville, near Birmingham.
1863. *Fernie, John. Box No. 2, Hutchinson, Kansas, U.S.A.
1910. *Ferranti, S. Z. de, M.Inst.C.E. Grindleford, near Sheffield.
1905. *FERRAR, H. T., M.A., F.G.S. Geological Survey of Egypt, Giza, Egypt.
1873. ‡FERRIER, Sir DAVID, M.A., M.D., LL.D., F.R.S. 34 Cavendish-square, W.
1909. ‡Fetherstonhaugh, Professor Edward P., B.Sc. 119 Betourney-street, Winnipeg, Canada.

Year of Election

1882. §Fewings, James, B.A., B.Sc. King Edward VI. Grammar School, Southampton.
1913. §Field, Miss E. E. Hollywood, Egham Hill, Surrey.
1897. ‡Field, George Wilton, Ph.D. Room 158, State House, Boston, Massachusetts, U.S.A.
1907. *Fields, Professor J. C., F.R.S. The University, Toronto, Canada.
1906. §Filon, L. N. G., D.Sc., F.R.S., Professor of Applied Mathematics in the University of London. Lynton, Haling Park-road, Croydon.
1905. ‡Fincham, G. H. Hopewell, Invami, Cape Colony.
1905. §Findlay, Alexander, M.A., Ph.D., D.Sc., Professor of Chemistry in University College, Aberystwyth.
1904. *Findlay, J. J., Ph.D., Professor of Education in the Victoria University, Manchester. Ruperra, Victoria Park, Manchester.
1912. §Finlayson, Daniel, F.L.S. Seed Testing Laboratory, Wood Green, N.
1902. ‡Finnegan, J., M.A., B.Sc. Kelvin House, Botanic-avenue, Belfast.
1902. ‡Fisher, J. R. Cranfield, Fortwilliam Park, Belfast.
1909. ‡Fisher, James, K.C. 216 Portage-avenue, Winnipeg, Canada.
1869. ‡Fisher, Rev. Osmond, M.A., F.G.S. Harlton Rectory, near Cambridge.
1875. *Fisher, W. W., M.A., F.C.S. 5 St. Margaret's-road, Oxford.
1887. *Fison, Alfred H., D.Sc. 47 Dartmouth-road, Willesden Green, N.W.
1871. *Fison, Sir Frederick W., Bart., M.A., F.C.S. Boarzell, Hurst Green, Sussex.
1885. *Fitzgerald, Professor Maurice, B.A. (Local Sec. 1902.) Fairholme, Monkstown, Co. Dublin.
1894. ‡Fitzmaurice, Sir Maurice, C.M.G., M.Inst.C.E. London County Council, Spring-gardens, S.W.
1888. *Fitzpatrick, Rev. Thomas C., President of Queens' College, Cambridge.
1904. ‡Flather, J. H., M.A. Camden House, 90 Hills-road, Cambridge.
1904. ‡Fleming, James. 25 Kelvinside-terrace South, Glasgow.
1913. §Fleming, Professor J. A., F.R.S. University College, Gower-street, W.C.
1892. ‡Fletcher, George, F.G.S. 53 Pembroke-road, Dublin.
1888. *Fletcher, Lazarus, M.A., Ph.D., F.R.S., F.G.S., F.C.S. (Pres. C, 1894), Director of the Natural History Museum, Cromwell-road, S.W. 35 Woodville-gardens, Ealing, W.
1908. *Fletcher, W. H. B. Aldwick Manor, Bognor, Sussex.
1901. ‡Flett, J. S., M.A., D.Sc., F.R.S., F.R.S.E. Geological Survey Office, 33 George-square, Edinburgh.
1906. *Fleure, H. J., D.Sc., Professor of Zoology and Geology in University College, Aberystwyth.
1905. *Flint, Rev. W., D.D. Houses of Parliament, Cape Town.
1913. *Florence, P. Sargant, B.A. Caius College, Cambridge.
1889. ‡Flower, Lady. 26 Stanhope-gardens, S.W.
1890. *Flux, A. W., M.A. Board of Trade, Gwydyr House, Whitehall, S.W.
1877. ‡Foale, William. The Croft, Madeira Park, Tunbridge Wells.
1903. ‡Foord-Kelcey, W., Professor of Mathematics in the Royal Military Academy, Woolwich. The Shrubbery, Shooter's Hill, S.E.
1911. ‡Foran, Charles. 72 Elm-grove, Southsea.
1906. §Forbes, Charles Mansfeldt. 14 New-street, York.
1873. *Forbes, George, M.A., F.R.S., F.R.S.E., M.Inst.C.E. 11 Little College-street, Westminster, S.W.

Year of Election.

1883. ‡FORBES, HENRY O., LL.D., F.Z.S., Redcliffe, Beaconsfield, Bucks.
1905. ‡FORBES, Major W. LACHLAN. Army and Navy Club, Pall Mall, S.W.
1875. *FORDHAM, Sir GEORGE. Odsey, Ashwell, Baldock, Herts.
1909. ‡FORGET, The Hon. A. E. Regina, Saskatchewan, Canada.
1887. ‡FORREST, The Right Hon. Sir JOHN, G.C.M.G., F.R.G.S., F.G.S. Perth, Western Australia.
1902. *Forster, M. O., Ph.D., D.Sc., F.R.S. 84 Cornwall-gardens, S.W.
1883. ‡FORSYTH, Professor A. R., M.A., D.Sc., F.R.S. (Pres. A, 1897, 1905; Council, 1907-09.) The Manor House, Marylebone, N.W.
1911. ‡Foster, F. G. Ivydale, London-road, Portsmouth.
1857. *FOSTER, GEORGE CAREY, B.A., LL.D., D.Sc., F.R.S. (GENERAL TREASURER, 1898–1904; Pres. A, 1877; Council, 1871–76, 1877–82). Ladywalk, Rickmansworth.
1908. **Foster, John Arnold.* 11 *Hills-place, Oxford Circus, W.*
1901. §Foster, T. Gregory, Ph.D., Provost of University College, London. University College, Gower-street, W.C.
1911. †FOSTER, Sir T. SCOTT, J.P. Town Hall, Portsmouth.
1911. †Foster, Lady Scott. Braemar, St. Helen's-parade, Southsea.
1903. ‡Fourcade, H. G. P.O., Storms River, Humansdorp, Cape Colony.
1905. §Fowlds, Hiram. 65 Devonshire-street, Keighley, Yorkshire.
1909. §Fowlds, Mrs. 65 Devonshire-street, Keighley, Yorkshire.
1912. ‡Fowler, A., F.R.S., Assistant Professor of Physics in the Imperial College of Science and Technology, S.W. 19 Rusthall-avenue, Bedford Park, W.
1906. §Fowler, Oliver H., M.R.C.S. Ashcroft House, Cirencester.
1883. *Fox, Charles. The Pynes, Warlingham-on-the-Hill, Surrey.
1883. ‡Fox, Sir CHARLES DOUGLAS, M.Inst.C.E. (Pres. G, 1896.) Cross Keys House, 56 Moorgate-street, E.C.
1904. *Fox, Charles J. J., B.Sc., Ph.D., Professor of Chemistry in the Presidency College of Science, Poona, India.
1904. §Fox, F. Douglas, M.A., M.Inst.C.E. 19 The Square, Kensington, W.
1905. ‡Fox, Mrs. F. Douglas. 19 The Square, Kensington, W.
1883. ‡Fox, Howard, F.G.S. Rosehill, Falmouth.
1847. *Fox, Joseph Hoyland. The Clive, Wellington, Somerset.
1900. *Fox. Thomas. Old Way House, Wellington, Somerset.
1909. *Fox, Wilson Lloyd. Carmino, Falmouth.
1908. §Foxley, Miss Barbara, M.A. 5 Norton Way North, Letchworth.
1881. *FOXWELL, HERBERT S., M.A., F.S.S. (Council, 1894–97), Professor of Political Economy in University College, London. St. John's College, Cambridge.
1907. *Fraine, Miss Ethel de, D.Sc., F.L.S. 27 Bargery-road, Catford, S.E.
1887. *FRANKLAND, PERCY F., Ph.D., B.Sc., F.R.S. (Pres. B, 1901), Professor of Chemistry in the University of Birmingham.
1910. *FRANKLIN, GEORGE, Litt.D. Tapton Hall, Sheffield.
1911. ‡FRASER, Dr. A. MEARNS. (Local Sec. 1911.) Town Hall, Portsmouth.
1911. ‡Fraser, Mrs. A. Mearns. Cheyne Lodge, St. Ronan's-road, Portsmouth.
1895. ‡Fraser, Alexander. 63 Church-street, Inverness.
1885. ‡FRASER, ANGUS, M.A., M.D., F.C.S. (Local Sec. 1885.) 232 Union-street, Aberdeen.
1871. ‡FRASER, Sir THOMAS R., M.D., F.R.S., F.R.S.E., Professor of Materia Medica and Clinical Medicine in the University of Edinburgh. 13 Drumsheugh-gardens, Edinburgh.
1911. §Freeman, Oliver, B.Sc. The Municipal College, Portsmouth.

Year of Election.

1884. *FREMANTLE, The Hon. Sir C. W., K.C.B. (Pres. F, 1892; Council, 1897–1903.) 4 Lower Sloane-street, S.W.
1906. §French, Fleet-Surgeon A. M. Langley, Beaufort-road, Kingston-on-Thames.
1909. ‡French, Mrs. Harriet A. Suite E, Gline's-block, Portage-avenue, Winnipeg, Canada.
1912. §French, Mrs. Harvey. Hambledon Lodge, Childe Okeford, Blandford.
1905. ‡French, Sir Somerset R., K.C.M.G. 100 Victoria-street, S.W.
1886. ‡FRESHFIELD, DOUGLAS W., F.R.G.S. (Pres. E, 1904.) 1 Airlie-gardens, Campden Hill, W.
1887. *Fries, Harold H., Ph.D. 92 Reade-street, New York, U.S.A.
1906. ‡FRITSCH, Dr. F. E. 77 Chatsworth-road, Brondesbury, N.W.
1912. §Frodsham, Miss Margaret, B.Sc. The College School, 34 Cathedral-road, Cardiff.
1892. *Frost, Edmund, M.D. Chesterfield-road, Eastbourne.
1882. §Frost, Edward P., J.P. West Wratting Hall, Cambridgeshire.
1911. ‡Frost, M. E. P. H.M. Dockyard, Portsmouth.
1887. *Frost, Robert, B.Sc. 55 Kensington-court, W.
1898. ‡FRY, The Right Hon. Sir EDWARD, G.C.B., D.C.L., LL.D., F.R.S., F.S.A. Failand House, Failand, near Bristol.
1908. ‡Fry, M. W. J., M.A. 39 Trinity College, Dublin.
1905. *Fry, William, J.P., F.R.G.S. Wilton House, Merrion-road, Dublin.
1898. ‡Fryer, Alfred C., Ph.D. 13 Eaton-crescent, Clifton, Bristol.
1872. *Fuller, Rev. A. 7 Sydenham-hill, Sydenham, S.E.
1912. §Fulton, Angus R., B.Sc. University College, Dundee.
1913. *Fyson, Philip Furley, B.A., F.L S. Elmley Lovett, Droitwich.

1910. ‡GADOW, H. F., Ph.D., F.R.S. (Pres. D., 1913). Zoological Laboratory, Cambridge.
1863. *Gainsford, W. D. Skendleby Hall, Spilsby.
1906. ‡Gajjar, Professor T. K., M.A., B.Sc. Techno-Chemical Laboratory, near Girgaum Tram Terminus, Bombay.
1885. *Gallaway, Alexander. Dirgarve, Aberfeldy, N.B.
1875. ‡GALLOWAY, W. Cardiff.
1887. *Galloway, W. J. The Cottage, Seymour-grove, Old Trafford, Manchester.
1905. ‡Galpin, Ernest E. Bank of Africa, Queenstown, Cape of Good Hope.
1913. §GAMBLE, F. W., D.Sc., F.R.S. (Local Sec., 1913), Professor of Zoology and Comparative Anatomy in the University of Birmingham. 38 Frederick-road, Edgbaston, Birmingham.
1888. *GAMBLE, J. SYKES, C.I.E., M.A., F.R.S., F.L.S. Highfield, East Liss, Hants.
1911. ‡Garbett, Rev. C. F., M.A. The Vicarage, Fratton-road, Portsmouth.
1899. *Garcke, E. Ditton House, near Maidenhead.
1898. ‡Garde, Rev. C. L. Skenfrith Vicarage, near Monmouth.
1911. ‡Gardiner, C. I., M.A., F.G.S. 6 Paragon-parade, Cheltenham.
1912. §Gardiner, F. A., F.L.S. Inversnaid, West Heath-avenue, N.W.
1905. ‡Gardiner, J. H. 59 Wroughton-road, Balham, S.W.
1900. ‡GARDINER, J. STANLEY, M.A., F.R.S., Professor of Zoology and Comparative Anatomy in the University of Cambridge. Zoological Laboratory, Cambridge.
1887. ‡GARDINER, WALTER, M.A., D.Sc., F.R.S. St. Awdreys, Hills-road, Cambridge.
1882. *Gardner, H. Dent, F.R.G.S. Fairmead, 46 The Goffs, Eastbourne.
1912. §Gardner, Willoughby, F.L.S. Y Berlfa, Deganwy, North Wales.

Year of Election.

1912. §Garfitt, G. A. Cartledge Hall, Holmesfield, near Sheffield.
1913. *Garnett, J. C. Maxwell. Westfield, Victoria Park, Manchester.
1905. ‡Garnett, Mrs. Maxwell, F.Z.S. Westfield, Victoria Park, Manchester.
1887. *Garnett, Jeremiah. The Grange, Bromley Cross, near Bolton, Lancashire.
1882. ‡Garnett, William, D.C.L. London County Council, Victoria Embankment, W.C.
1883. ‡GARSON, J. G., M.D. (ASSIST. GEN. SEC. 1902–04.) Moorcote, Eversley, Winchfield.
1903. ‡Garstang, A. H. 82 Forest-road, Southport.
1903. *Garstang, T. James, M.A. Bedales School, Petersfield, Hampshire.
1894. *GARSTANG, WALTER, M.A., D.Sc., F.Z.S., Professor of Zoology in the University of Leeds.
1874. *Garstin, John Ribton, M.A., LL.B., M.R.I.A., F.S.A. Bragans-town, Castlebellingham, Ireland.
1889. ‡GARWOOD, E. J., M.A., F.G.S. (Pres. C, 1913), Professor of Geology in the University of London. University College, Gower-street, W.C.
1905. ‡Gaskell, Miss C. J. The Uplands, Great Shelford, Cambridge.
1905. ‡Gaskell, Miss M. A. The Uplands, Great Shelford, Cambridge.
1896. *GASKELL, WALTER HOLBROOK, M.A., M.D., LL.D., F.R.S. (Pres. I, 1896; Council, 1898–1901.) The Uplands, Great Shelford, Cambridge.
1906. ‡Gaster, Leon. 32 Victoria-street, S.W.
1913. §GATES, R. R., Ph.D., F.L.S. 14 Well-walk, Hampstead, N.W.
1911. ‡Gates, W. 'Evening News' Office, Portsmouth.
1912. §Gavin, W., B.A. Hatfield Wick, Hatfield Peverel, Essex.
1905 *Gearon, Miss Susan. 55 Buckleigh-road, Streatham Common, S.W.
1885. ‡GEDDES, Professor PATRICK. 14 Ramsay-gardens, Edinburgh.
1867. ‡GEIKIE, Sir ARCHIBALD, O.M., K.C.B., LL.D., D.Sc., F.R.S., F.R.S.E., F.G.S. (PRESIDENT, 1892; Pres. C, 1867, 1871, 1899; Council, 1888–1891.) Shepherd's Down, Haslemere, Surrey.
1871. ‡GEIKIE, JAMES, LL.D., D.C.L., F.R.S., F.R.S.E., F.G.S. (Pres. C, 1889; Pres. E, 1892), Murchison Professor of Geology and Mineralogy in the University of Edinburgh. Kilmorie, Colinton-road, Edinburgh.
1913. §Geldart, Miss Alice M. 2 Cotman-road, Norwich.
1898. *GEMMILL, JAMES F., M.A., M.D. 12 Anne-street, Hillhead, Glasgow.
1882. *GENESE, R. W., M.A., Professor of Mathematics in University College, Aberystwyth.
1905. ‡Gentleman, Miss A. A. 9 Abercromby-place, Stirling.
1912. *George, H. Trevelyan, M.A., M.R.C.S., L.R.C.P. 33 Ampthill-square, N.W.
1902. *Gepp, Antony, M.A., F.L.S. British Museum (Natural History), Cromwell-road, S.W.
1899. *Gepp, Mrs A. British Museum (Natural History), Cromwell-road, S.W.
1913. §Gerich, Miss Emma A. P. Care of The Manager, Bank of Australasia, Sydney, Australia.
1884. *Gerrans, Henry T., M.A. 20 St. John-street, Oxford.
1909. ‡GIBBONS, W. M., M.A. (Local Sec. 1910.) The University, Sheffield.
1905 ‡Gibbs, Miss Lilian S., F.L.S. 22 South-street, Thurloe-square, S.W.

Year of
Election.

1912. ‡Gibson, A. H., D.Sc., Professor of Engineering in University College, Dundee.
1912. ‡Gibson, G. E., Ph.D., B.Sc. 16 Woodhall-terrace, Juniper Green.
1901. ‡Gibson, Professor George A., M.A. 10 The University, Glasgow.
1876. *Gibson, George Alexander, M.D., D.Sc., LL.D., F.R.S.E. 3 Drumsheugh-gardens, Edinburgh.
1904. *Gibson, Mrs. Margaret D., LL.D. Castle Brae, Chesterton-lane, Cambridge.
1912. *Gibson, Miss Mary H., M.A., Ph.D. 75 Colum-road, Cardiff.
1896. ‡GIBSON, R. J. HARVEY, M.A., F.R.S.E., Professor of Botany in the University of Liverpool.
1889. *Gibson, T. G. Lesbury House, Lesbury, R.S.O., Northumberland.
1893. ‡Gibson, Walcot, F.G.S. 28 Jermyn-street, S.W.
1898. *Gifford, J. William. Oaklands, Chard.
1883. §Gilbert, Lady. Park View, Englefield Green, Surrey.
1884. *Gilbert, Philip H. 63 Tupper-street, Montreal, Canada.
1895. ‡GILCHRIST, J. D. F., M.A., Ph.D., B.Sc., F.L.S. Marine Biologist's Office, Department of Agriculture, Cape Town.
1896. *GILCHRIST, PERCY C., F.R.S., M.Inst.C.E. Reform Club, Pall Mall, S.W.
1871. *GILL, Sir DAVID, K.C.B., LL.D., D.Sc., F.R.S., Hon.F.R.S.E. (PRESIDENT, 1907.) 34 De Vere-gardens, Kensington, W.
1911. ‡Gill, Rev. H. V., S.J. Milltown Park, Clonskea, Co. Dublin.
1902. ‡Gill, James F. 72 Strand-road, Bootle, Liverpool.
1908. ‡Gill, T. P. Department of Agriculture and Technical Instruction for Ireland, Dublin.
1913. *Gillett, Joseph A., B.A. Woodgreen, Banbury.
1913. §Gillmor, R. E. 57 Victoria-street, S.W.
1892. *Gilmour, Matthew A. B., F.Z.S. Saffronhall House, Windmill-road, Hamilton, N.B.
1907. ‡Gilmour, S. C. 25 Cumberland-road, Acton, W.
1908. ‡*Gilmour, T. L. 1 St. John's Wood Park, N.W.*
1913. §Gilson, R. Cary, M.A. King Edward's School, Birmingham.
1913. §Gimingham, C. T., F.I.C. Research Station, Long Ashton, Bristol.
1893. *Gimingham, Edward. Croyland, Clapton Common, N.
1904. ‡GINN, S. R., D.L. (Local Sec. 1904.) Brookfield, Trumpington-road, Cambridge.
1884. ‡Girdwood, G. P., M.D. 615 University-street, Montreal, Canada.
1886. *Gisborne, Hartley, M.Can.S.C.E. Yoxall, Ladysmith, Vancouver Island, Canada.
1883. *Gladstone, Miss. 19 Chepstow-villas, Bayswater, W.
1871. *GLAISHER, J. W. L., M.A., D.Sc., F.R.S., F.R.A.S. (Pres. A, 1890; Council, 1878–86.) Trinity College, Cambridge.
1880. *GLANTAWE, Right Hon. Lord. The Grange, Swansea.
1881. *GLAZEBROOK, R. T., C.B., M.A., D.Sc., F.R.S. (Pres. A, 1893; Council 1890–94, 1905–11), Director of the National Physical Laboratory. Bushy House, Teddington, Middlesex.
1881. *Gleadow, Frederic. 38 Ladbroke-grove, W.
Glover, Thomas. 124 Manchester-road, Southport.
1878. *Godlee, J. Lister. Wakes Colne Place, Essex.
1880. ‡GODMAN, F. DU CANE, D.C.L., F.R.S., F.L.S., F.G.S. 45 Pont-street, S.W.
1879. ‡GODWIN-AUSTEN, Lieut.-Colonel H. H., F.R.S., F.R.G.S., F.Z.S. (Pres. E, 1883.) Nore, Godalming.
1878. ‡GOFF, JAMES. (Local Sec. 1878.) 29 Lower Leeson-street, Dublin.
1908. *GOLD, ERNEST, M.A. 8 Hurst Close, Bigwood-road, Hampstead Garden Suburb, N.W.

Year of Election.

1906. ‡GOLDIE, Right Hon. Sir GEORGE D. T., K.C.M.G., D.C.L., F.R.S. (Pres. E, 1906; Council, 1906–07.) 44 Rutland-gate, S.W.
1910. §Golding, John, F.I.C. University College, Reading.
1913. §Golding, Mrs. University College, Reading.
1899. ‡GOMME, Sir G. L., F.S.A. 24 Dorset-square, N.W.
1890. *GONNER, E. C. K., M.A. (Pres. F, 1897), Professor of Political Economy in the University of Liverpool.
1909. ‡Goodair, Thomas. 303 Kennedy-street, Winnipeg, Canada.
1912. §Goodman, Sydney C. M., B.A. 4 Paper-buildings, Temple, E.C.
1907. §GOODRICH, E. S., M.A., F.R.S., F.L.S. Merton College, Oxford.
1908. ‡Goodrich, Mrs. Merton College, Oxford.
1884. *Goodridge, Richard E. W. P.O. Box 36, Coleraine, Minnesota, U.S.A.
1884. ‡Goodwin, Professor W. L. Queen's University, Kingston, Ontario, Canada.
1909. §Gordon, Rev. Charles W. 567 Broadway, Winnipeg, Canada.
1909. ‡Gordon, J. T. 147 Hargrave-street, Winnipeg, Canada.
1909. ‡Gordon, Mrs. J. T. 147 Hargrave-street, Winnipeg, Canada.
1911. *Gordon, J. W. 113 Broadhurst-gardens, Hampstead, N.W.
1871. *Gordon, Joseph Gordon, F.C.S. Queen Anne's-mansions, Westminster, S.W.
1893. ‡Gordon, Mrs. M. M. Ogilvie, D.Sc. 1 Rubislaw-terrace, Aberdeen.
1910. *Gordon, Vivian. Avonside Engine Works, Fishponds, Bristol.
1912. §Gordon, W. T. 1 Suffolk-road, Edinburgh.
1901. ‡GORST, Right Hon. Sir JOHN E., M.A., K.C., M.P., F.R S. (Pres. L, 1901.) 84 Campden Hill Court, W.
1881. ‡Gough, Rev. Thomas, B.Sc. King Edward's School, Retford.
1901. ‡GOURLAY, ROBERT. Glasgow.
1876. ‡Gow, Robert. Cairndowan, Dowanhill-gardens, Glasgow.
1883 ‡Gow, Mrs. Cairndowan, Dowanhill-gardens, Glasgow.
1873. ‡Goyder, Dr. D. Marley House, 88 Great Horton-road, Bradford, Yorkshire.
1908. *GRABHAM, G. W., M.A., F.G.S. P.O. Box 178, Khartoum, Sudan.
1886. ‡Grabham, Michael C., M.D. Madeira.
1909. ‡GRACE, J. H., M.A., F.R.S. Peterhouse, Cambridge.
1909. ‡Graham, Herbert W. 329 Kennedy-street, Winnipeg, Canada.
1902. *Graham, William, M.D. Purdysburn House, Belfast.
1875. ‡GRAHAME, JAMES. (Local Sec. 1876.) Care of Messrs. Grahame, Crums, & Connal, 34 West George-street, Glasgow.
1904. §Gramont, Comte Arnaud de, D.Sc. 179 rue de l'Université, Paris.
1896. ‡Grant, Sir James, K.C.M.G. Ottawa, Canada.
1908. *Grant, Professor W. L. Queen's University, Kingston, Ontario.
1890. ‡GRAY, ANDREW, M.A., LL.D., F.R.S., F.R.S.E., Professor of Natural Philosophy in the University of Glasgow.
1864. *Gray, Rev. Canon Charles. West Retford Rectory, Retford.
1881. ‡Gray, Edwin, LL.B. Minster-yard, York.
1903. §Gray, Ernest, M.A. 99 Grosvenor-road, S.W.
1904. ‡*Gray, Rev. H. B., D.D. (Pres. L, 1909). 13 St. George's-road, S.W.*
1892. *Gray, James Hunter, M.A., B.Sc. 3 Crown Office-row, Temple, E.C.
1887. ‡Gray, Joseph W., F.G.S. 6 Richmond Park-crescent, Bournemouth.
1887. ‡Gray, M. H., F.G.S. Lessness Park, Abbey Wood, Kent.
1886. *Gray, Robert Kaye. Lessness Park, Abbey Wood, Kent.
1901. ‡Gray, R. Whytlaw. University College, W.C.
1873. ‡Gray, William, M.R.I.A. Glenburn Park, Belfast.

Year of Election.

*GRAY, Colonel WILLIAM. Farley Hall, near Reading.
1866. §Greaves, Charles Augustus, M.B., LL.B. 84 Friar-gate, Derby.
1910. ‡Greaves, R. H., B.Sc. 12 St. John's-crescent, Cardiff.
1904. *Green, Professor A. G., M.Sc. The Old Gardens, Cardigan-road, Headingley, Leeds.
1904. §Green, F. W. 5 Wordsworth-grove, Cambridge.
1906. §Green, J. A., M.A., Professor of Education in the University of Sheffield.
1888. §GREEN, J. REYNOLDS, M.A., D.Sc., F.R.S., F.L.S. (Pres. K, 1902.) Downing College, Cambridge.
1903. ‡*Green, W. J. 76 Alexandra-road, N.W.*
1908. ‡Green, Rev. William Spotswood, C.B., F.R.G.S. 5 Cowper-villas, Cowper-road, Dublin.
1909. ‡Greenfield, Joseph. P.O. Box 2935, Winnipeg, Canada.
1882. ‡GREENHILL, Sir A. G., M.A., F.R.S. 1 Staple Inn, W.C.
1905. ‡Greenhill, William. 6A George-street, Edinburgh.
1913. *Greenland, Miss Lucy Maud. St. Hilda's, Hornsea, East Yorkshire.
1898. *GREENLY, EDWARD, F.G.S. Achnashean, near Bangor, North Wales.
1875. ‡Greenwood, Dr. Frederick. Brampton, Chesterfield.
1906. ‡Greenwood, Hamar. National Liberal Club, Whitehall-place, S.W.
1894. *GREGORY, J. WALTER, D.Sc., F.R.S., F.G.S. (Pres. C, 1907), Professor of Geology in the University of Glasgow.
1896. *GREGORY, Professor R. A., F.R.A.S. Walcot, Blyth-road, Bromley, Kent.
1904. *GREGORY, R. P., M.A. St. John's College, Cambridge.
1914. §Grew, Mrs. 30 Cheyne-row, S.W.
1894. *Griffith, C. L. T., Assoc.M.Inst.C.E., Professor of Civil Engineering in the College of Engineering, Madras.
1908. §Griffith, Sir John P., M.Inst.C.E. Rathmines Castle, Rathmines, Dublin.
1884. ‡GRIFFITHS, E. H., M.A., D.Sc., F.R.S. (Pres. A, 1906; Pres. L, 1913; Council, 1911-), Principal of University College, Cardiff.
1884. ‡Griffiths, Mrs. University College, Cardiff.
1903. ‡Griffiths, Thomas, J.P. 101 Manchester-road, Southport.
1888. *Grimshaw, James Walter, M.Inst.C.E. St. Stephen's Club, Westminster, S.W.
1911. ‡Grogan, Ewart S. Camp Hill, near Newcastle, Staffs.
1894. ‡GROOM, Professor P., M.A., F.L.S. North Park, Gerrard's Cross, Bucks.
1894. ‡Groom, T. T., M.A., D.Sc., F.G.S., Professor of Geology in the University of Birmingham.
1909. *Grossman, Edward L., M.D. Steilacoom, Washington, U.S.A.
1896. ‡Grossmann, Dr. Karl. 70 Rodney-street, Liverpool.
1913. §Grove, W. B., M.A. 45 Duchess-road, Edgaston, Birmingham.
1869. ‡GRUBB, Sir HOWARD, F.R.S., F.R.A.S. Aberfoyle, Rathgar, Dublin.
1913. §Gruchy, G. F. B. de. 18A St. James's-court, Buckingham-gate, S.W.
1897. ‡Grünbaum, A. S., M.A., M.D. School of Medicine, Leeds.
1910. §Grundy, James. Ruislip, Teignmouth-road, Cricklewood, N.W.
1913. §Guest, James J. 11 St. Mark's-road, Leamingham.
1887 ‡GUILLEMARD, F. H. H., M.A., M.D. The Mill House, Trumpington, Cambridge.
1905. *Gunn, Donald. Royal Societies Club, St. James's-street, S.W.
1909. ‡Gunne, J. R., M.D. Kenora, Ontario, Canada.
1909. ‡Gunne, W. J., M.D. Kenora, Ontario, Canada.

Year of Election.

1866. ‡GÜNTHER, ALBERT C. L. G., M.A., M.D., Ph.D., F.R.S., F.L.S., F.Z.S. (Pres. D, 1880.) 22 Lichfield-road, Kew, Surrey.
1894. ‡Günther, R. T. Magdalen College, Oxford.
1880. §Guppy, John J. Ivy-place, High-street, Swansea.
1904. §Gurney, Sir Eustace. Sprowston Hall, Norwich.
1902 *Gurney, Robert. Ingham Old Hall, Stalham, Norfolk.
1904. ‡Guttmann, Professor Leo F., Ph.D. Queen's University, Kingston, Canada.
1895. *GWYNNE-VAUGHAN, D. T., F.L.S., Professor of Botany in Queen's University, Belfast.
1906. *GWYNNE-VAUGHAN, Mrs. HELEN C. I., D.Sc., F.L.S. Department of Botany, Birkbeck College; and 27 Lincoln's Inn-fields, W.C.

1905. ‡Hacker, Rev. W. J. Idutywa, Transkei, South Africa.
1908. *Hackett, Felix E. Royal College of Science, Dublin.
1881. *HADDON, ALFRED CORT, M.A., D.Sc., F.R.S., F.Z.S. (Pres. H, 1902, 1905; Council, 1902–08, 1910– .) 3 Cranmer-road, Cambridge.
1914. §Haddon, Mrs. 3 Cranmer-road, Cambridge.
1911. *Haddon, Miss Kathleen. 3 Cranmer-road, Cambridge.
1888. *Hadfield, Sir Robert, D.Met., D.Sc., F.R.S., M.Inst.C.E. 22 Carlton House-terrace, S.W.
1913. §Hadley, H. E., B.Sc. School of Science, Kidderminster.
1905. ‡Hahn, Professor P. H., M.A., Ph.D. York House, Gardens, Cape Town.
1911. ‡Haigh, B. P., B.Sc. James Watt Engineering Laboratory, The University, Glasgow.
1906. ‡Hake, George W. Oxford, Ohio, U.S.A.
1894. ‡HALDANE, JOHN SCOTT, M.A., M.D., F.R.S. (Pres. I, 1908), Reader in Physiology in the University of Oxford. Cherwell, Oxford.
1909. §Hale, W. H., Ph.D. 40 First-place, Brooklyn, New York, U.S.A.
1911. §Halket, Miss A. C. Waverley House, 135 East India-road, E.
1899. ‡HALL, A. D., M.A., F.R.S. (Council, 1908– .) Development Commission, 6A Dean's-yard, S.W.
1914. §Hall, Mrs. A. D. 6A Dean's-yard, S.W.
1909. §Hall, Archibald A., M.Sc., Ph.D. Armstrong College, Newcastle-on-Tyne.
1903. ‡HALL, E. MARSHALL, K.C. 75 Cambridge-terrace, W.
1879. *Hall, Ebenezer. Abbeydale Park, near Sheffield.
1913. §Hall-Edwards, J. The Elms, 112 Gough-road, Edgaston, Birmingham.
1883. *Hall, Miss Emily. 63 Belmont-street, Southport.
1854. *HALL, HUGH FERGIE, F.G.S. Cissbury Court, West Worthing, Sussex.
1899. ‡Hall, John, M.D. National Bank of Scotland, Nicholas-lane, E.C.
1884. §Hall, Thomas Proctor, M.D. 1301 Davie-street, Vancouver, B.C., Canada.
1908. *Hall, Wilfred, Assoc.M.Inst.C.E. 9 Prior's-terrace, Tynemouth, Northumberland.
1891. *Hallett, George. Cranford, Victoria-square, Penarth.
1873. *HALLETT, T. G. P., M.A. Claverton Lodge, Bath.
1888. §HALLIBURTON, W. D., M.D., LL.D., F.R.S. (Pres. I, 1902; Council, 1897–1903, 1911–), Professor of Physiology in King's College, London. Church Cottage, 17 Marylebone-road, N.W.
1905. ‡Halliburton, Mrs. Church Cottage, 17 Marylebone-road, N.W.
1904. *Hallidie, A. H. S. Avondale, Chesterfield-road, Eastbourne.
1908. *Hamel, Egbert Alexander de. Middleton Hall, Tamworth.

Year of Election.

1883. *Hamel, Egbert D. de. Middleton Hall, Tamworth.
1904. *Hamel de Manin, Anna Countess de. 35 Circus-road, N.W.
1906. ‡Hamill, John Molyneux, M.A., M.B. 14 South-parade, Chiswick.
1906. ‡Hamilton, Charles I. 88 Twyford-avenue, Acton.
1909. ‡Hamilton, F. C. Bank of Hamilton-chambers, Winnipeg, Canada.
1902. ‡Hamilton, Rev. T., D.D. Queen's College, Belfast.
1909. ‡Hamilton, T. Glen, M.D. 264 Renton-avenue, Winnipeg, Canada.
1881. *Hammond, Robert, M.Inst.C.E. 64 Victoria-street, Westminster, S.W.
1899. *Hanbury, Daniel. Lenqua da Cà, Alassio, Italy.
1878. ‡Hance, E. M. Care of J. Hope Smith, Esq., 3 Leman-street, E.C.
1909. ‡Hancock, C. B. Manitoba Government Telephones, Winnipeg, Canada.
1905. *Hancock, Strangman. Kennel Holt, Cranbrook, Kent.
1912. ‡Hankin, G. T. 150 Whitehall-court, S.W.
1911. ‡Hann, H. F. 139 Victoria-road North, Southsea.
1906. §Hanson, David. Salterlee, Halifax, Yorkshire.
1904. §Hanson, E. K. 2A The Parade, High-street, Watford; and Woodthorpe, Royston Park-road, Hatch End, Middlesex.
1859. *Harcourt, A. G. Vernon, M.A., D.C.L., LL.D., D.Sc., F.R.S., V.P.C.S. (Gen. Sec. 1883–97; Pres. B, 1875; Council, 1881–83.) St. Clare, Ryde, Isle of Wight.
1909. §Harcourt, George. Department of Agriculture, Edmonton, Alberta, Canada.
1886. *Hardcastle, Colonel Basil W., F.S.S. 12 Gainsborough-gardens, Hampstead, N.W.
1902. *Hardcastle, Miss Frances. 3 Osborne-terrace, Newcastle-on-Tyne.
1903. *Hardcastle, J. Alfred. The Dial House, Crowthorne, Berkshire.
1892. *Harden, Arthur, Ph.D., D.Sc., F.R.S. Lister Institute of Preventive Medicine, Chelsea-gardens, Grosvenor-road, S.W.
1905. ‡*Hardie, Miss Mabel, M.B. High-lane,* via *Stockport.*
1877. ‡Harding, Stephen. Bower Ashton, Clifton, Bristol.
1894. ‡Hardman, S. C. 120 Lord-street, Southport.
1913. §Hardy, George Francis. 30 Edwardes-square, Kensington, W.
1909. §Hardy, W. B., M.A., F.R.S. Gonville and Caius College, Cambridge.
1881. ‡Hargrove, William Wallace. St. Mary's, Bootham, York
1890. *Harker, Alfred, M.A., F.R.S., F.G.S. (Pres. C, 1911.) St. John's College, Cambridge.
1896. ‡Harker, John Allen, D.Sc., F.R.S. National Physical Laboratory, Bushy House, Teddington.
1875. *Harland, Rev. Albert Augustus, M.A., F.G.S., F.L.S., F.S.A. The Vicarage, Harefield, Middlesex.
1877. *Harland, Henry Seaton. 8 Arundel-terrace, Brighton.
1883. *Harley, Miss Clara. Rastrick, Cricketfield-road, Torquay.
1899. ‡Harman, Dr. N. Bishop, F.R.C.S. 108 Harley street, W.
1913. §Harmar, Mrs. 102 Hagley-road, Birmingham.
1868. *Harmer, F. W., F.G.S. Oakland House, Cringleford, Norwich.
1881. *Harmer, Sidney F., M.A., Sc.D., F.R.S. (Pres. D, 1908), Keeper of the Department of Zoology, British Museum (Natural History), Cromwell-road, S.W.
1912. *Harper, Alan G., B.A. Magdalen College, Oxford.
1906. ‡Harper, J. B. 16 St. George's-place, York.
1913. §Harris, F. W. 132 and 134 Hurst-street, Birmingham.
1842. *Harris, G. W. Millicent, South Australia.
1909. ‡Harris, J. W. Civic Offices, Winnipeg.

Year of Election.

1903. ‡Harris, Robert, M.B. Queen's-road, Southport.
1904. *Harrison, Frank L., B.A., B.Sc. Brook-street, Soham, Cambridgeshire.
1904. ‡HARRISON, H. SPENCER. The Horniman Museum, Forest Hill, S.E.
1892. ‡HARRISON, JOHN. (Local Sec. 1892.) Rockville, Napier-road, Edinburgh.
1892. ‡Harrison, Rev. S. N. Ramsey, Isle of Man.
1901. *Harrison, W. E. 17 Soho-road, Handsworth, Staffordshire.
1911. ‡Harrison-Smith, F., C.B. H.M. Dockyard, Portsmouth.
1885. ‡HART, Colonel C. J. (Local Sec. 1886.) Highfield Gate, Edgbaston. Birmingham.
1909. ‡Hart, John A. 120 Emily-street, Winnipeg, Canada.
1876. *Hart, Thomas. Brooklands, Blackburn.
1903. *Hart, Thomas Clifford. Brooklands, Blackburn.
1907. §Hart, W. E. Kilderry, near Londonderry.
1911. ‡Hart-Synnot, Ronald V.O. University College, Reading.
1893. *HARTLAND, E. SIDNEY, F.S.A. (Pres. H, 1906; Council, 1906-13). Highgarth, Gloucester.
1905. ‡Hartland, Miss. Highgarth, Gloucester.
1886. *HARTOG, Professor M. M., D.Sc. University College, Cork.
1887. ‡HARTOG, P. J., B.Sc. University of London, South Kensington, S.W.
1885. ‡Harvie-Brown, J. A., LL.D. Dunipace, Larbert, N.B.
1862. *Harwood, John. Woodside Mills, Bolton-le-Moors.
1893. §Haslam, Lewis. 8 Wilton-crescent, S.W.
1911. *Hassé, H. R. The University, Manchester.
1903. *Hastie, Miss J. A. Care of Messrs. Street & Co., 30 Cornhill, E.C.
1904. ‡HASTINGS, G. 23 Oak-lane, Bradford, Yorkshire.
1875. *HASTINGS, G. W. (Pres. F, 1880.) Chapel House, Chipping Norton.
1903. ‡Hastings, W. G. W. 2 Halsey-street, Cadogan-gardens, S.W.
1889. ‡HATCH, F. H., Ph.D., F.G.S. Southacre, Trumpington-road, Cambridge.
1903. ‡Hathaway, Herbert G 45 High-street, Bridgnorth, Salop.
1904. *Haughton, W. T. H. The Highlands, Great Barford, St. Neots.
1908. §Havelock, T. H., M.A., D.Sc. Rockliffe, Gosforth, Newcastle-on-Tyne.
1904. ‡Havilland, Hugh de. Eton College, Windsor.
1887. *Hawkins, William. Earlston House, Broughton Park, Manchester.
1872. *Hawkshaw, Henry Paul. 58 Jermyn-street, St. James's, S.W.
1864. *HAWKSHAW, JOHN CLARKE, M.A., M.Inst.C.E., F.G.S. (Council, 1881-87.) 22 Down-street, W.
1897. §HAWKSLEY, CHARLES, M.Inst.C.E., F.G.S. (Pres. G, 1903; Council, 1902-09.) Caxton House (West Block), Westminster, S.W.
1887. *Haworth, Jesse. Woodside, Bowdon, Cheshire.
1913. §Haworth, John F. Withens, Barker-road, Sutton Coldfield.
1913. §Haworth, Mrs. Withens, Barker-road, Sutton Coldfield.
1885. *HAYCRAFT, JOHN BERRY, M.D., B.Sc., F.R.S.E., Professor of Physiology in University College, Cardiff.
1900. §Hayden, H. H., B.A., F.G.S. Geological Survey, Calcutta, India.
1903. *Haydock, Arthur. 114 Revidge-road, Blackburn.
1913. §Hayward, Miss. 7 Abbotsford-road, Galashiels, N.B.
1903. ‡Hayward, Joseph William, M.Sc. Keldon, St. Marychurch, Torquay.
1896. *Haywood, Colonel A. G. Rearsby, Merrilocks-road, Blundelllsands.
1883. ‡Heape, Joseph R. Glebe House, Rochdale.
1882. *Heape, Walter, M.A., F.R.S. 10 King's Bench-walk, Temple, E.C.

Year of Election.

1909. §Heard, Mrs. Sophie, M.B., Ch.B. Carisbrooke, Fareham, Hants.
1908. §Heath, J. St. George, B.A. Woodbrooke Settlement, Selly Oak, near Birmingham.
1902. ‡Heath, J. W. Royal Institution, Albemarle-street, W.
1898. ‡HEATH, R. S., M.A., D.Sc., Vice-Principal and Professor of Mathematics in the University of Birmingham.
1909. ‡Heathcote, F. C. C. Broadway, Winnipeg, Canada.
1883. ‡Heaton, Charles. Marlborough House, Hesketh Park, Southport.
1913. §HEATON, HOWARD. (Local Sec., 1913.) Wayside, Lode-lane, Solihull, Birmingham.
1892. *HEATON, WILLIAM H., M.A. (Local Sec., 1893), Principal and Professor of Physics in University College, Nottingham.
1889. *Heaviside, Arthur West, I.S.O. 12 Tring-avenue, Ealing, W.
1888. *HEAWOOD, EDWARD, M.A. Briarfield, Church-hill, Merstham, Surrey.
1888. *Heawood, Percy J., Professor of Mathematics in Durham University. High Close, Hollinside-lane, Durham.
1887. *HEDGES, KILLINGWORTH, M.Inst.C.E. 10 Cranley-place, South Kensington, S.W.
1912. §Hedley, Charles. Australian Museum, Sydney.
1881. *HELE-SHAW, H. S., D.Sc., LL.D., F.R.S., M.Inst.C.E. 64 Victoria-street, S.W.
1901. *HELLER, W. M., B.Sc. 59 Upper Mount-street, Dublin.
1911. ‡Hellyer, Francis E. Farlington House, Havant, Hants.
1911. ‡Hellyer, George E. Farlington House, Havant, Hants.
1887. ‡Hembry, Frederick William, F.R.M.S. City-chambers, 2 St. Nicholas-street, Bristol.
1908. ‡Hemmy, Professor A. S. Government College, Lahore.
1899. ‡Hemsalech, G. A., D.Sc. The Owens College, Manchester.
1905. *Henderson, Andrew. 17 Belhaven-terrace, Glasgow.
1905. *Henderson, Miss Catharine. 17 Belhaven-terrace, Glasgow.
1891. *HENDERSON, G. G., D.Sc., M.A., F.I.C., Professor of Chemistry in the Glasgow and West of Scotland Technical College, Glasgow.
1905. §Henderson, Mrs. 7 Marlborough-drive, Kelvinside, Glasgow.
1907. §Henderson, H. F. Felday, Morland-avenue, Leicester.
1906. ‡Henderson, J. B., D.Sc., Professor of Applied Mechanics in the Royal Naval College, Greenwich, S.E.
1909. ‡Henderson, Veylien E. Medical Building, The University, Toronto, Canada.
1880. *Henderson, Admiral W. H., R.N. 3 Onslow Houses, S.W.
1911. §Henderson, William Dawson. The University, Bristol.
1904. *Hendrick, James. Marischal College, Aberdeen.
1910. ‡Heney, T. W. Sydney, New South Wales.
1910. *HENRICI, Captain E. O., R.E., A.Inst.C.E. Ordnance Survey Office, Southampton.
1873. *HENRICI, OLAUS M. F. E., Ph.D., F.R.S. (Pres. A, 1883 ; Council, 1883–89.) Hiltingbury Lodge, Chandler's Ford, Hants.
1910. ‡Henry, Hubert, M.D. 304 Glossop-road, Sheffield.
1906. ‡Henry, Dr. T. A. Imperial Institute, S.W.
1909. *Henshall, Robert. Sunnyside, Latchford, Warrington.
1892. ‡HEPBURN, DAVID, M.D., F.R.S.E., Professor of Anatomy in University College, Cardiff.
1904. ‡Hepworth, Commander M. W. C., C.B., R.N.R. Meteorological Office, South Kensington, S.W.
1892. *HERBERTSON, A. J., M.A., Ph.D. (Pres. E, 1910), Professor of Geography in the University of Oxford. 9 Fyfield-road, Oxford.

Year of Election.

1909. ‡Herbinson, William. 376 Ellice-avenue, Winnipeg, Canada.
1902. ‡Herdman, G. W., B.Sc., Assoc.M.Inst.C.E. Irrigation and Water Supply Department, Pretoria.
1912. *Herdman, George Andrew. Croxteth Lodge, Sefton Park, Liverpool.
1887. *HERDMAN, WILLIAM A., D.Sc., F.R.S., F.R.S.E., F.L.S. (GENERAL SECRETARY, 1903- ; Pres. D, 1895; Council, 1894–1900; Local Sec. 1896), Professor of Natural History in the University of Liverpool. Croxteth Lodge, Sefton Park, Liverpool.
1893. *Herdman, Mrs. Croxteth Lodge, Sefton Park, Liverpool.
1909. ‡Herdt, Professor L. A. McGill University, Montreal, Canada.
1875. ‡HEREFORD, The Right Rev. JOHN PERCIVAL, D.D., LL.D., Lord Bishop of. (Pres. L, 1904.) The Palace, Hereford.
1912. ‡Heron, David, D.Sc. Galton Eugenics Laboratory, University College, W.C.
1912. §Heron-Allen, Edward, F.L.S., F.G.S. 33 Hamilton-terrace, N.W.
1908. *Herring, Percy T., M.D. The University, St. Andrews, N.B.
1874. §HERSCHEL, Colonel JOHN, R.E., F.R.S., F.R.A.S. Observatory House, Slough, Bucks.
1900. *Herschel, Rev. J. C. W. Fircroft, Wellington College Station, Berkshire.
1913. §Hersey, Mayo Dyer, A.M. Bureau of Standards, Washington, U.S.A.
1905. ‡Hervey, Miss Mary F. S. 22 Morpeth-mansions, S.W.
1903. *HESKETH, CHARLES H. FLEETWOOD, M.A. Stocken Hall, Stretton, Oakham.
1895. §Hesketh, James. 5 Scarisbrick Avenue, Southport.
1913. §Hett, Miss May L. 53 Fordwych-road, West Hampstead, N.W.
1894. ‡HEWETSON, G. H. (Local Sec. 1896.) 39 Henley-road, Ipswich.
1894. ‡*Hewins, W. A. S., M.A., F.S.S. 15 Chartfield-avenue, Putney Hill, S.W.*
1908. ‡Hewitt, Dr. C. Gordon. Central Experimental Farm, Ottawa.
1896. §Hewitt, David Basil, M.D. Oakleigh, Northwich, Cheshire.
1903. ‡Hewitt, E. G. W. 87 Princess-road, Moss Side, Manchester.
1909. §Hewitt, Sir Frederic, M.V.O., M.D. 14 Queen Anne-street, W.
1903. ‡Hewitt, John Theodore, M.A., D.Sc., Ph.D., F.R.S. Clifford House, Staines-road, Bedfont, Middlesex.
1909. ‡Hewitt, W., B.Sc. 16 Clarence-road, Birkenhead.
1882. *HEYCOCK, CHARLES T., M.A., F.R.S. 3 St. Peter's-terrace, Cambridge.
1883. ‡Heyes, Rev. John Frederick, M.A., F.R.G.S. St. Barnabas Vicarage, Bolton.
1866. *Heymann, Albert. West Bridgford, Nottinghamshire.
1901. *Heys, Z. John. Stonehouse, Barrhead, N.B.
1912. §Heywood, H. B., D.Sc. Pinner, Middlesex.
1912. §Hickling, George. The University, Manchester.
1877. §HICKS, W. M., M.A., D.Sc., F.R.S. (Pres. A, 1895), Professor of Physics in the University of Sheffield. Leamhurst, Ivy Park-road, Sheffield.
1886. ‡Hicks, Mrs. W. M. Leamhurst, Ivy Park-road, Sheffield.
1887. *HICKSON, SYDNEY J., M.A., D.Sc., F.R.S. (Pres. D, 1903), Professor of Zoology in Victoria University, Manchester.
1864. *HIERN, W. P., M.A., F.R.S. The Castle, Barnstaple.
1891. ‡HIGGS, HENRY, C.B., LL.B., F.S.S. (Pres. F, 1899; Council, 1904–06.) H.M. Treasury, Whitehall, S.W.
1909. ‡Higman, Ormond. Electrical Standards Laboratory, Ottawa.
1913. *Higson, G. I., M.Sc. 11 Westbourne-road, Birkdale, Lancashire.

Year of Election.

1907. ‡HILEY, E. V. (Local Sec. 1907.) Town Hall, Birmingham.
1911. *Hiley, Wilfrid E. Ebbor, Wells, Somerset.
1885. *HILL, ALEXANDER, M.A., M.D. Hartley University College, Southampton.
1903. *HILL, ARTHUR W., M.A., F.L.S. Royal Gardens, Kew.
1906. §Hill, Charles A., M.A., M.B. 13 Rodney-street, Liverpool.
1881. *HILL, Rev. EDWIN, M.A. The Rectory, Cockfield, Bury St. Edmunds.
1908. *HILL, JAMES P., D.Sc., F.R.S., Professor of Zoology in University College, Gower-street, W.C.
1911. §HILL, LEONARD, M.B., F.R.S. (Pres. I, 1912.) Osborne House, Loughton, Essex.
1912. §Hill, M. D. Angelo's, Eton College, Windsor.
1886. ‡HILL, M. J. M., M.A., D.Sc., F.R.S., Professor of Pure Mathematics in University College, W.C.
1898. *Hill, Thomas Sidney. Langford House, Langford, near Bristol.
1888. ‡Hill, William, F.G.S. The Maples, Hitchin, Herts.
1907. *HILLS, Major E. H., C.M.G., R.E., F.R.S., F.R.G.S. (Pres. E, 1908.) 32 Prince's-gardens, S.W.
1911. *Hills, William Frederick Waller. 32 Prince's-gardens, S.W.
1903. *Hilton, Harold. 108 Alexandra-road, South Hampstead, N W.
1903. *HIND, WHEELTON, M.D., F.G.S. Roxeth House, Stoke-on-Trent.
1870. ‡HINDE, G. J., Ph.D., F.R.S., F.G.S. Ivythorn, Avondale-road, South Croydon, Surrey
1910. §Hindle, Edward, B.A., Ph.D., F.L.S. Quick Laboratories, Cambridge.
1883. *Hindle, James Henry. 8 Cobham-street, Accrington.
1898. §Hinds, Henry. 57 Queen-street, Ramsgate.
1911. ‡Hinks, Arthur R., M.A., F.R.S., Assist. Sec. R.G.S. Royal Geographical Society, Kensington Gore, S.W.
1903. *Hinmers, Edward. Glentwood, South Downs-drive, Hale, Cheshire.
1911. ‡*Hitchcock, Miss A. M., M.A.* 40 *St. Andrew's-road, Southsea.*
1899. ‡Hobday, Henry. Hazelwood, Crabble Hill, Dover.
1887. *HOBSON, BERNARD, M.Sc., F.G.S. Thornton, Hallamgate-road, Sheffield.
1904. ‡HOBSON, ERNEST WILLIAM, Sc.D., F.R.S. (Pres. A, 1910), Sadlerian Professor of Pure Mathematics in the University of Cambridge, The Gables, Mount Pleasant, Cambridge.
1907. ‡Hobson, Mrs. Mary. 6 Hopefield-avenue, Belfast.
1877. ‡Hodge, Rev. John Mackey, M.A. 38 Tavistock-place, Plymouth.
1913. §Hodges, Ven. Archdeacon George, M.A. Ely.
1887. *Hodgkinson, Alexander, M.B., B.Sc., Lecturer on Laryngology in the Victoria University, Manchester. 18 St. John-street, Manchester.
1880. ‡Hodgkinson, W. R. Eaton, Ph.D., F.R.S.E., F.G.S., Professor of Chemistry and Physics in the Royal Artillery College, Woolwich. 18 Glenluce-road, Blackheath, S.E.
1912. ‡Hodgson, Benjamin. The University, Bristol.
1905. ‡Hodgson, Ven. Archdeacon R. The Rectory, Wolverhampton.
1909. ‡Hodgson, R. T., M.A. Collegiate Institute, Brandon, Manitoba, Canada.
1898. ‡Hodgson, T. V. Municipal Museum and Art Gallery, Plymouth.
1904. *Hodson, F., Ph.D. Bablake School, Coventry.
1907. ‡Hodson, Mrs. Bablake School, Coventry.
1904. ‡HOGARTH, D. G., M.A. (Pres. H, 1907 ; Council, 1907-10.) 20 St. Giles's, Oxford.
1908. ‡Hogg, Right Hon. Jonathan. Stratford, Rathgar, Co. Dublin.

Year of Election.

1911. ‡Holbrook, Colonel A. R. Warleigh, Grove-road South, Southsea.
1907. ‡Holden, Colonel H. C. L., C.B., R.A., F.R.S. Gifford House, Blackheath, S.E.
1883. ‡Holden, John J. 73 Albert-road, Southport.
1887. *Holder, Henry William, M.A. Beechmount, Arnside.
1913. §Holder, Sir John C., Bart. Pitmaston, Moor Green, Birmingham.
1900. ‡HOLDICH, Colonel Sir THOMAS H., R.E., K.C.B., K.C.I.E., F.R.G.S. (Pres. E, 1902.) 41 Courtfield-road, S.W.
1887. *Holdsworth, C. J., J.P. Fernhill, Alderley Edge, Cheshire.
1904. §Holland, Charles E. 9 Downing-place, Cambridge.
1903. §Holland, J. L., B.A. 3 Primrose-hill, Northampton.
1896. ‡Holland, Mrs. Lowfields House, Hooton, Cheshire.
1898. ‡HOLLAND, Sir THOMAS H., K.C.I.E., F.R.S., F.G.S., Professor of Geology in the Victoria University, Manchester.
1889. ‡Holländer, Bernard, M.D. 35A Welbeck-street, W.
1906. *Hollingworth, Miss. Leithen, Newnham-road, Bedford.
1883. *Holmes, Mrs. Basil. 23 Corfton-road, Ealing, Middlesex, W.
1866. *Holmes, Charles. Makeney, Compton-road, Winchmore Hill, N.
1882. *HOLMES, THOMAS VINCENT, F.G.S. 28 Croom's-hill, Greenwich, S.E.
1912. ‡Holmes-Smith, Edward, B.Sc. Royal Botanic Gardens, Edinburgh.
1903. *HOLT, ALFRED, M.A., D.Sc. Dowsefield, Allerton, Liverpool.
1875. *Hood, John. Chesterton, Cirencester.
1904. §Hooke, Rev. D. Burford, D.D. Somerset Lodge, Barnet.
1908. *Hooper, Frank Henry. Deepdene, Streatham Common, S.W.
1865. *Hooper, John P. Deepdene, Streatham Common, S.W.
1877. *Hooper, Rev. Samuel F., M.A. Lydlinch Rectory, Sturminster Newton, Dorset.
1904. ‡Hopewell-Smith, A., M.R.C.S. 37 Park-street, Grosvenor-square, S.W.
1905. *Hopkins, Charles Hadley. Junior Constitutional Club, 101 Piccadilly, W.
1913. §HOPKINS, F. GOWLAND, M.A., D.Sc., M.B., F.R.S. (Pres. I, 1913). Trinity College, and Saxmeadham, Grange-road, Cambridge.
1901. *HOPKINSON, BERTRAM, M.A., F.R.S., F.R.S.E., Professor of Mechanism and Applied Mechanics in the University of Cambridge. 10 Adams-road, Cambridge.
1884. *HOPKINSON, CHARLES. (Local Sec. 1887.) The Limes, Didsbury, near Manchester.
1882. *Hopkinson, Edward, M.A., D.Sc. Ferns, Alderley Edge, Cheshire.
1871. *HOPKINSON, JOHN, Assoc.Inst.C.E., F.L.S., F.G.S., F.R.Met.Soc. Weetwood, Watford.
1905. ‡Hopkinson, Mrs. John. Labrande, Adams-road, Cambridge.
1898. *Hornby, R., M.A. Haileybury College, Hertford.
1910. §Horne, Arthur S. Kerlegh, Cobham, Surrey.
1885. ‡HORNE, JOHN, LL.D., F.R.S., F.R.S.E., F.G.S. (Pres. C, 1901.) 12 Keith-crescent, Blackhall, Midlothian.
1903. ‡Horne, William, F.G.S. Leyburn, Yorkshire.
1902. ‡Horner, John. Chelsea, Antrim-road, Belfast.
1905. *Horsburgh, E. M., M.A., B.Sc., Lecturer in Technical Mathematics in the University of Edinburgh.
1887. ‡Horsfall, T. C. Swanscoe Park, near Macclesfield.
1893. *HORSLEY, Sir VICTOR A. H., LL.D., B.Sc., F.R.S., F.R.C.S. (Council, 1893–98.) 25 Cavendish-square, W.
1908. ‡Horton, F. St. John's College, Cambridge.
1884. *Hotblack, G. S. Brundall, Norwich.
1899. ‡Hotblack, J. T., F.G.S. 45 Newmarket-road, Norwich.
1906. *Hough, Miss Ethel M. Codsall Wood, near Wolverhampton.

Year of Election.

1859. ‡Hough, Joseph, M.A., F.R.A.S. Codsall Wood, Wolverhampton.
1896. *Hough, S. S., M.A., F.R.S., F.R.A.S., His Majesty's Astronomer at the Cape of Good Hope. Royal Observatory, Cape Town.
1905. §Houghting, A. G. L. Glenelg, Musgrave-road, Durban, Natal.
1886. ‡Houghton, F. T. S., M.A., F.G.S. 188 Hagley-road, Birmingham.
1908. ‡Houston, David, F.L.S. Royal College of Science, Dublin.
1893. ‡Howard, F. T., M.A., F.G.S. West Mount, Waverton, near Chester.
1904. *Howard, Mrs. G. L. C. Agricultural Research Institute, Pusa, Bengal, India.
1887. *Howard, S. S. 54 Albemarle-road, Beckenham, Kent.
1901. §Howarth, E., F.R.A.S. Public Museum, Weston Park, Sheffield.
1903. *Howarth, James H., F.G.S. Holly Bank, Halifax.
1907. ‡Howarth, O. J. R., M.A. (Assistant Secretary.) 24 Lansdowne-crescent, W.
1911. *Howe, Professor G. W. O., M.Sc. City and Guilds Engineering College, Exhibition-road, S.W.
1905. ‡Howick, Dr. W. P.O. Box 503, Johannesburg.
1863. ‡Howorth, Sir H. H., K.C.I.E., D.C.L., F.R.S., F.S.A. 30 Collingham-place, Cromwell-road, S.W.
1887. §Hoyle, William E., M.A., D.Sc. (Pres. D, 1907.) National Museum of Wales, City Hall, Cardiff.
1903. ‡Hübner, Julius. Ash Villa, Cheadle Hulme, Cheshire.
1913. §Huddart, Mrs. J. A. 2 Chatsworth-gardens, Eastbourne.
1898. ‡Hudson, Mrs. Sunny Bank, Egerton, Huddersfield.
1867. *Hudson, Professor William H. H., M.A., LL.M. 34 Birdhurst-road, Croydon.
1913. §Hughes, Professor Alfred. 29 George-road, Edgbaston, Birmingham.
1871. *Hughes, George Pringle, J.P., F.R.G.S. Middleton Hall, Wooler, Northumberland.
1868. ‡Hughes, T. M'K., M.A., F.R.S., F.G.S. (Council, 1879–86), Woodwardian Professor of Geology in the University of Cambridge. Ravensworth, Brooklands-avenue, Cambridge.
1912. §Hukling, George. The University, Manchester.
1867. ‡Hull, Edward, M.A., LL.D., F.R.S., F.G.S. (Pres. C, 1874.) 14 Stanley-gardens, Notting Hill, W.
1903. ‡Hulton, Campbell G. Palace Hotel, Southport.
1905. §Hume, D. G. W. 55 Gladstone-street, Dundee, Natal.
1911. *Hume, Dr. W. F. Helwan, Egypt.
1904. *Humphreys, Alexander C., Sc.D., LL.D., President of the Stevens Institute of Technology, Hoboken, New Jersey, U.S.A.
1913. §Humphreys, John, F.G.S. (Local Sec. 1913.) 26 Clarendon-road, Edgbaston, Birmingham.
1907. §Humphries, Albert E. Coxe's Lock Mills, Weybridge.
1877. *Hunt, Arthur Roope, M.A., F.G.S. Southwood, Torquay.
1891. *Hunt, Cecil Arthur, Southwood, Torquay.
1881. ‡Hunter, F. W. 16 Old Elvet, Durham.
1889. ‡Hunter, Mrs. F. W. 16 Old Elvet, Durham.
1909. ‡Hunter, W. J. H. 31 Lynedoch-street, Glasgow.
1901. *Hunter, William. Evirallan, Stirling.
1903. ‡Hurst, Charles C., F.L.S. Burbage, Hinckley.
1861. *Hurst, William John. Drumaness, Ballynahinch, Co. Down, Ireland.
1913. §Hutchins, Miss B. L. The Glade, Branch Hill, Hampstead Heath, N.W.
1914. §Hutchins, D. E. Medo House, Cobham, Kent.

Year of Election.

1894. *HUTCHINSON, A., M.A., Ph.D. (Local Sec. 1904.) Pembroke College, Cambridge.
1912. §Hutchinson, Dr. H. B. Rothamsted Experimental Station, Harpenden, Herts.
1903. §Hutchinson, Rev. H. N. 17 St. John's Wood Park, Finchley-road, N.W.
1864. *Hutton, Darnton. 14 Cumberland-terrace, Regent's Park, N.W.
1887. *Hutton, J. Arthur. The Woodlands, Alderley Edge, Cheshire.
1901. *Hutton, R. S., D.Sc. West-street, Sheffield.
1871. *Hyett, Francis A. Painswick House, Painswick, Stroud, Gloucestershire.
1900. *Hyndman, H. H. Francis. 5 Warwick-road, Earl's Court, S.W.

1908. ‡Idle, George. 43 Dawson-street, Dublin.
1883. ‡Idris, T. H. W. 110 Pratt-street, Camden Town, N.W.
1884. *Iles, George. 5 Brunswick-street, Montreal, Canada.
1906. ‡Iliffe, J. W. Oak Tower, Upperthorpe, Sheffield.
1913. §Illing, Vincent Charles, B.A., F.G.S. The Chestnuts, Hartshill, Atherstone, Warwickshire.
1885. §IM THURN, Sir EVERARD F., C.B., K.C.M.G. (Council 1913–). 39 Lexham-gardens, W.
1907. §Ingham, Charles B. Moira House, Eastbourne.
1901. ‡INGLIS, JOHN, LL.D. 4 Prince's-terrace, Dowanhill, Glasgow.
1905. §Innes, R. T. A., F.R.A.S. Union Observatory, Johannesburg.
1901. *Ionides, Stephen A. 929 Foster-building, Denver, Colorado.
1913. §Irvine, James, F.R.G.S. Richmond-buildings, Chapel-street, Liverpool.
1912. §Irvine, Professor J. C. The University, St. Andrews.
1882. §IRVING, Rev. A., B.A., D.Sc. Hockerill Vicarage, Bishop's Stortford, Herts.
1908. ‡Irwin, Alderman John. 33 Rutland-square, Dublin.

1876. *JACK, WILLIAM, LL.D., Professor of Mathematics in the University of Glasgow. 10 The University, Glasgow.
1909. ‡Jacks, Professor L. P. 28 Holywell, Oxford.
1883. *Jackson, Professor A. H., B.Sc. 349 Collins-street, Melbourne, Australia.
1903. ‡Jackson, C. S. Royal Military Academy, Woolwich, S.E.
1874. *Jackson, Frederick Arthur. Belmont, Somenos, Vancouver Island, B.C., Canada.
1883. *Jackson, F. J. 35 Leyland-road, Southport.
1883. ‡Jackson, Mrs. F. J. 35 Leyland-road, Southport.
1899. ‡Jackson, Geoffrey A. 31 Harrington-gardens, Kensington, S.W.
1913. *Jackson, H. Gordon, M.Sc. Mason College, Birmingham.
1906. *Jackson, James Thomas, M.A. Engineering School, Trinity College, Dublin.
1898. *Jackson, Sir John. 51 Victoria-street, S.W.
1887. §Jacobson, Nathaniel, J.P. Olive Mount, Cheetham Hill-road, Manchester.
1905. *Jaffé, Arthur, M.A. 3 King's Bench-walk, Temple, E.C.
1874. *Jaffé, John. Villa Jaffé, 38 Promenade des Anglais, Nice, France.
1906. ‡Jalland, W. H. Museum-street, York.
1891. *James, Charles Henry, J.P. 64 Park-place, Cardiff.
1891. *James, Charles Russell. The Bungalow, Redhill, Surrey.
1904. ‡James, Thomas Campbell. University College, Aberystwyth.

Year of Election.

1896. *Jameson, H. Lyster, M.A., Ph.D. Borderdale, Sunningdale, Berks.
1889. *JAPP, F. R., M.A., Ph.D., LL.D., F.R.S. (Pres. B, 1898), Professor of Chemistry in the University of Aberdeen.
1910. *Japp, Henry, M.Inst.C.E. Care of Messrs. S. Pearson & Son, 507 Fifth Avenue, New York, U.S.A.
1896. *Jarmay, Gustav. Hartford Lodge, Hartford, Cheshire.
1913. §Jarrard, W. J. The University, Sheffield.
1903. ‡JARRATT, J. ERNEST (Local Sec. 1903). 10 Cambridge-road, Southport.
1904. *Jeans, J. H., M.A., F.R.S. 8 Ormonde-gate, Chelsea, S.W.
1897. ‡Jeffrey, E. C., B.A. The University, Toronto, Canada.
1912. §Jehu, T. J., M.A., M.D., Professor of Geology in the University of St. Andrews.
1908. *Jenkin, Arthur Pearse, F.R.Met.Soc. Trewirgie, Redruth.
1909. *Jenkins, Miss Emily Vaughan. 31 Antrim-mansions, South Hampstead, N.W.
1903. ‡Jenkinson, J. W. The Museum, Oxford.
1904. ‡Jenkinson, W. W. 6 Moorgate-street, E.C.
1893. ‡Jennings, G. E. 60 Fosse-road South, Leicester.
1905. ‡Jennings, Sydney. P.O. Box 149, Johannesburg.
Jessop, William. Overton Hall, Ashover, Chesterfield.
1900. *Jevons, H. Stanley, M.A , B.Sc. 3 Pembroke-terrace, Cardiff.
1907. *Jevons, Miss H. W. Enderley, Little Kingshill, Great Missenden, Bucks.
1905. §Jeyes, Miss Gertrude, B.A. Berrymead, 6 Lichfield-road, Kew Gardens.
1909. *Johns, Cosmo, F.G.S., M.I.M.E. Burngrove, Pitsmoor-road, Sheffield.
1909. ‡Johnson, C. Kelsall, F.R.G.S. The Glen, Sidmouth, Devon.
1913. §Johnson, Dr. S. J. Department of Biology, The University, Sydney, N.S.W.
1890. *JOHNSON, THOMAS, D.Sc., F.L.S., Professor of Botany in the Royal College of Science, Dublin.
1902. *Johnson, Rev. W., B.A., B.Sc. Archbishop Holgate's Grammar School, York.
1898. *Johnson, W. Claude, M.Inst.C.E. Broadstone, Coleman's Hatch, Sussex.
1899. ‡JOHNSTON, Colonel Sir DUNCAN A., K.C.M.G., C.B., R.E., Hon. Sec. R.G.S. (Pres. E, 1909.) Branksome, Down View-road, West Worthing.
1883. ‡JOHNSTON, Sir H. H., G.C.M.G., K.C.B., F.R.G.S. St. John's Priory, Poling, near Arundel.
1913. §Johnston, James. Oak Bank-avenue, Manchester.
1909. *Johnston, J. Weir, M.A. 20 Ely-place, Dublin.
1908. ‡Johnston, Swift Paine. 1 Hume-street, Dublin.
1884. *Johnston, W. H. County Offices, Preston, Lancashire.
1885. ‡JOHNSTON-LAVIS, H. J., M.D., F.G.S. Beaulieu, Alpes-Maritimes, France.
1909. §Jolly, Professor W. A., M.B., D.Sc. South African College, Cape Town.
1888. ‡JOLY, JOHN, M.A., D.Sc., F.R.S., F.G.S. (Pres. C, 1908), Professor of Geology and Mineralogy in the University of Dublin. Geological Department, Trinity College, Dublin.
1887. ‡Jones, D. E., B.Sc. Eryl Dag, Radyr, Cardiff.
1913. *Jones, Daniel, M.A., Lecturer on Phonetics at University College, London, W.C.
1904. ‡Jones, Miss E. E. Constance. Girton College, Cambridge.

Year of Election.

1890. §JONES, Rev. EDWARD, F.G.S. Primrose Cottage, Embsay, Skipton.
1896. ‡Jones, E. Taylor, D.Sc. University College, Bangor.
1903. §Jones, Evan. Ty-Mawr, Aberdare.
1907. *Jones, Mrs. Evan. 39 Hyde Park-gate, S.W.
1887. ‡Jones, Francis, F.R.S.E., F.C.S. Beaufort House, Alexandra Park, Manchester.
1891. *JONES, Rev. G. HARTWELL, D.D. Nutfield Rectory, Redhill, Surrey.
1883. *Jones, George Oliver, M.A. Inchyra House, 21 Cambridge-road, Waterloo, Liverpool.
1912. ‡Jones, J. H. The University, Glasgow.
1913. §Jones, O. T., M.A., D.Sc., F.G.S., Professor of Geology in the University College of Wales. Fenton, Caradoc-road, Aberystwyth.
1905. ‡Jones, Miss Parnell. The Rectory, Llanddewi Skyrrid, Abergavenny, Monmouthshire.
1901. ‡Jones, R. E., J.P. Oakley Grange, Shrewsbury.
1902. ‡Jones, R. M., M.A. Royal Academical Institution, Belfast.
1908. ‡Jones, R. Pugh, M.A. County School, Holyhead, Anglesey.
1912. §Jones, W. Neilson. University College, Reading.
1875. *Jose, J. E. Ethersall, Tarbock-road, Huyton, Lancashire.
1913. §Jourdain, Miss Eleanor F. St. Hugh's College, Oxford.
1883. ‡Joyce, Rev. A. G., B.A. St. John's Croft, Winchester.
1886. ‡Joyce, Hon. Mrs. St. John's Croft, Winchester.
1905. ‡Judd, Miss Hilda M., B.Sc. Berrymead, 6 Lichfield-road, Kew.
1870. ‡JUDD, JOHN WESLEY, C.B., LL.D., F.R.S., F.G.S. (Pres. C, 1885; Council, 1886-92.) Orford Lodge, 30 Cumberland-road, Kew.
1894. §Julian, Mrs. Forbes. Redholme, Braddon's Hill-road, Torquay.
1905. §Juritz, Charles F., M.A., D.Sc., F.I.C., Chief of the Division of Chemistry, Union of South Africa. Department of Agriculture, Cape Town.

1913. §Kannreuther, E. H. Richmond Hill House, Edgbaston, Birmingham.
1888. ‡KAPP, GISBERT, M.Sc., M.Inst.C.E., M.Inst.E.E. (Pres. G, 1913), Professor of Electrical Engineering in the University of Birmingham. Pen-y-Coed, Pritchatts-road, Birmingham.
1913. §Kay, Henry, F.G.S. 16 Wretham-road, Handsworth, Birmingham.
1913. §Kaye, G. W. C. Culver, St. James'-avenue, Hampton Hill.
1904. ‡Kayser, Professor H. The University, Bonn, Germany.
1892. ‡KEANE, CHARLES A., Ph.D. Sir John Cass Technical Institute, Jewry-street, Aldgate, E.C.
1913. §Kebby, Charles H. 75 Sterndale-road, West Kensington Park, W.
1908. §KEEBLE, FREDERICK, M.A., Sc.D., F.R.S. (Pres. K, 1912), Professor of Botany in University College, Reading.
1913. *Keeling, B. F. E. Survey Department, Giza Branch, Egypt.
1911. *Keith, Arthur, M.D., LL.D., F.R.S., F.R.C.S. Royal College of Surgeons, Lincoln's Inn-fields, W.C.
1884. ‡Kellogg, J. H., M.D. Battle Creek, Michigan, U.S.A.
1908. ‡Kelly, Sir Malachy. Ard Brugh, Dalkey, Co. Dublin.
1908. ‡Kelly, Captain Vincent Joseph. Montrose, Donnybrook, Co. Dublin.
1911. ‡Kelly, Miss. Montrose, Merton-road, Southsea.
1902. *Kelly, William J., J.P. 25 Oxford-street, Belfast.
1885. §KELTIE, J. SCOTT, LL.D., Sec. R.G.S., F.S.S. (Pres. E, 1897; Council, 1898-1904.) Royal Geographical Society, Kensington Gore, S.W.

Year of Election.

1877. *Kelvin, Lady. Netherhall, Largs, Ayrshire; and 15 Eaton-place, S.W.
1887. ‡Kemp, Harry. 55 Wilbraham-road, Chorlton-cum-Hardy, Manchester.
1898. *Kemp, John T., M.A. 4 Cotham-grove, Bristol.
1884. ‡Kemper, Andrew C., A.M., M.D. 101 Broadway, Cincinnati, U.S.A.
1891. ‡KENDALL, PERCY F., M.Sc., F.G.S., Professor of Geology in the University of Leeds.
1875. ‡KENNEDY, Sir ALEXANDER B. W., LL.D., F.R.S., M.Inst.C.E. (Pres. G, 1894.) 1 Queen Anne-street, Cavendish-square, W.
1897. §Kennedy, George, M.A., LL.D., K.C. Crown Lands Department, Toronto, Canada.
1906. ‡Kennedy, Robert Sinclair. Glengall Ironworks, Millwall, E.
1908. ‡Kennedy, William. 40 Trinity College, Dublin.
1905. *Kennerley, W. R. P.O. Box 158, Pretoria.
1913. §KENRICK, Sir G. H. Whetstone, Somerset-road, Edgbaston, Birmingham.
1913. §KENRICK, W. BYNG. (Local Sec. 1913.) Metchley House, Somerset-road, Edgbaston, Birmingham.
1893. §KENT, A. F. STANLEY, M.A., F.L.S., F.G.S., Professor of Physiology in the University of Bristol.
1901. ‡Kent, G. 16 Premier-road, Nottingham.
1913. *Kenyon, Joseph, B.Sc., F.I.C. 51 Irving-place, Blackburn.
1857. *Ker, André Allen Murray. Newbliss House, Newbliss, Ireland.
1881. ‡KERMODE, P. M. C. Claghbene, Ramsey, Isle of Man.
1913. §Kerr, George L. 39 Elmbank-crescent, Glasgow.
1909. ‡Kerr, Hugh L. 68 Admiral-road, Toronto, Canada.
1892. ‡KERR, J. GRAHAM, M.A., F.R.S., Regius Professor of Zoology in the University of Glasgow.
1889. ‡Kerry, W. H. R. The Sycamores, Windermere.
1910. §Kershaw, J. B. C. West Lancashire Laboratory, Waterloo, Liverpool.
1869. *Kesselmeyer, Charles Augustus. Roseville, Vale-road, Bowdon, Cheshire.
1869. *Kesselmeyer, William Johannes. Edelweiss Villa, Albert-road, Hale, Cheshire.
1903. ‡Kewley, James. Balek Papan, Koltei, Dutch Borneo.
1883. *Keynes, J. N., M.A., D.Sc., F.S.S. 6 Harvey-road, Cambridge.
1902. ‡*Kidd, George. Greenhaven, Malone Park, Belfast.*
1906. ‡Kidner, Henry, F.G.S. 25 Upper Rock-gardens, Brighton.
1886. §KIDSTON, ROBERT, LL.D., F.R.S., F.R.S.E., F.G.S. 12 Clarendon-place, Stirling.
1901. *Kiep, J. N. 137 West George-street, Glasgow.
1885. *Kilgour, Alexander. Loirston House, Cove, near Aberdeen.
1896. *Killey, George Deane, J.P. Bentuther, 11 Victoria-road, Waterloo, Liverpool.
1890. ‡KIMMINS, C. W., M.A., D.Sc. Canon's House, St. Thomas-street, Southwark, S.E.
1875. *KINCH, EDWARD, F.I.C., Professor of Chemistry in the Royal Agricultural College, Cirencester.
*1875. King, F. Ambrose. Avonside, Clifton, Bristol.
1871. *King, Rev. Herbert Poole. The Rectory, Stourton, Bath.
1883. *King, John Godwin. Stonelands, East Grinstead.
1883. *King, Joseph, M.P. Sandhouse, Witley, Godalming.
1908. §King, Professor L. A. L., M.A. St. Mungo's College Medical School, Glasgow.
1860. *King, Mervyn Kersteman. Merchants' Hall, Bristol.

Year of Election.

1875. *King, Percy L. 15 The Avenue, Clifton, Bristol.
1912. *King, W. B. R., B.A., F.G.S. Geological Survey, Jermyn-street, S.W.
1912. ‡King, W. J. Harding. 25 York House, Kensington, W.
1870. ‡King, William, M.Inst.C.E. 5 Beach-lawn, Waterloo, Liverpool.
1913. *King, William Wickham, F.G.S. Winds Point, Hagley, near Stourbridge.
1909. ‡Kingdon, A. 197 Yale-avenue, Winnipeg, Canada.
1903. ‡Kingsford, H. S., M.A. 8 Elsworthy-terrace, N.W.
1900. ‡KIPPING, Professor F. STANLEY, D.Sc., Ph.D., F.R.S. (Pres. B, 1908.) University College, Nottingham.
1899. *Kirby, Miss C. F. 8 Windsor-court, Moscow-road, W.
1913. §Kirkaldy, Professor A. W., M.Com. The University, Edmund street, Birmingham.
1901. §Kitto, Edward. 2 Great Headland-terrace, Preston, Paignton, South Devon.
1886. ‡Knight, Captain J. M., F.G.S. Bushwood, Wanstead, Essex.
1912. §Knipe, Henry R., F.L.S., F.G.S. 9 Linden-park, Tunbridge Wells.
1888. ‡KNOTT, Professor CARGILL G., D.Sc., F.R.S.E. 42 Upper Gray-street, Edinburgh.
1887. *Knott, Herbert, J.P. Sunnybank, Wilmslow, Cheshire.
1887. *Knott, John F. Edgemoor, Burbage, Derbyshire.
1906. *Knowles, Arthur J., B.A., M.Inst.C.E. Turf Club, Cairo, Egypt.
1874. ‡Knowles, William James. Flixton-place, Ballymena, Co. Antrim.
1902. ‡KNOX, R. KYLE, LL.D. 1 College-gardens, Belfast.
1875. *Knubley, Rev. E. P., M.A. Steeple Ashton Vicarage, Trowbridge.
1883. ‡Knubley, Mrs. Steeple Ashton Vicarage, Trowbridge.
1890. *Krauss, John Samuel, B.A. Stonycroft, Knutsford-road, Wilmslow, Cheshire.
1888 *Kunz, G. F., M.A., Ph.D. Care of Messrs. Tiffany & Co., 11 Union-square, New York City, U S.A.

1903. *Lafontaine, Rev. H. C. de. 52 Albert-court, Kensington Gore, S.W.
1909. ‡Laird, Hon. David. Indian Commission, Ottawa, Canada.
1904. ‡Lake, Philip. St. John's College, Cambridge.
1904. ‡Lamb, C. G. Ely Villa, Glisson-road, Cambridge.
1889. *Lamb, Edmund, M.A. Borden Wood, Liphook, Hants.
1887. ‡LAMB, HORACE, M.A., LL.D., D.Sc., F.R.S. (Pres. A, 1904), Professor of Mathematics in the Victoria University, Manchester. 6 Wilbraham-road, Fallowfield, Manchester.
1903. ‡*Lambert, Joseph. 9 Westmoreland-road, Southport.*
1893. *LAMPLUGH, G. W., F.R.S., F.G.S. (Pres. C, 1906.) 13 Beaconsfield-road, St. Albans.
1898. *LANG, WILLIAM H., F.R.S. 2 Heaton-road, Withington, Manchester.
1886. *LANGLEY, J. N., M.A., D.Sc., F.R.S. (Pres. I, 1899; Council, 1904–07), Professor of Physiology in the University of Cambridge. Trinity College, Cambridge.
1865. ‡LANKESTER, Sir E. RAY, K.C.B., M.A., LL.D., D.Sc., F.R.S. (PRESIDENT, 1906; Pres. D, 1883; Council, 1889–90, 1894–95, 1900–02.) 331 Upper Richmond-road, Putney, S.W.
1880. *LANSDELL, Rev. HENRY, D.D., F.R.A.S., F.R.G.S. Dimsdale, 4 Pond-road, Blackheath Park, London, S.E.
1884. ‡Lanza, Professor G. Massachusetts Institute of Technology, Boston, U.S.A.
1911. ‡Lapthorn, Miss. St. Bernard's, Grove-road South, Southsea.

Year of Election.

1885. ‡LAPWORTH, CHARLES, LL.D., F.R.S., F.G.S. (Pres. C, 1892.) 38 Calthorpe-road, Edgbaston, Birmingham.
1909. §Larard, C. E., Assoc.M.Inst. C.E. 106 Cranley-gardens, Muswell Hill, N.
1887. ‡Larmor, Alexander. Craglands, Helen's Bay, Co. Down.
1881. ‡LARMOR, Sir JOSEPH, M.A., D.Sc., F.R.S. (Pres. A, 1900), Lucasian Professor of Mathematics in the University of Cambridge. St. John's College, Cambridge.
1883. ‡Lascelles, B. P., M.A. Headland, Mount Park, Harrow.
1870. *LATHAM, BALDWIN, M.Inst.C.E., F.G.S. Parliament-mansions, Westminster, S.W.
1911. §Lattey, R. T. Royal Naval College, Dartmouth.
1900. †Lauder, Alexander, Lecturer in Agricultural Chemistry in the Edinburgh and East of Scotland College of Agriculture, Edinburgh.
1911. §Laurie, Miss C. L. 1 Vittoria-walk, Cheltenham.
1913. *Laurie, Mrs. E. B. 11 Marine-parade, Hoylake.
1892. ‡LAURIE, MALCOLM, B.A., D.Sc., F.L.S. School of Medicine, Surgeons' Hall, Edinburgh.
1907. *Laurie, Robert Douglas. Department of Zoology, The University, Liverpool.
1870. *Law, Channell. Ilsham Dene, Torquay.
1905. ‡Lawrence, Miss M. Roedean School, near Brighton.
1911. *Lawson, A. Anstruther, D.Sc., F.R.S.E., F.L.S. The University, Sydney, N.S.W.
1908. ‡Lawson, H. S., B.A. Buxton College, Derbyshire.
1908. ‡Lawson, William, LL.D. 27 Upper Fitzwilliam-street, Dublin.
1888. ‡Layard, Miss Nina F., F.L.S. Rookwood, Fonnereau-road, Ipswich.
1913. §Lea, F. C., D.Sc. 36 Mayfield-road, Moseley, Birmingham.
1883. *Leach, Charles Catterall. Seghill, Northumberland.
1894. *LEAHY, A. H., M.A., Professor of Mathematics in the University of Sheffield. 92 Ashdell-road, Sheffield.
1905. ‡Leake, E. O. 5 Harrison-street, Johannesburg.
1901. *Lean, George, B.Sc. 15 Park-terrace, Glasgow.
1904. *Leathem, J. G. St. John's College, Cambridge.
1884. *Leavitt, Erasmus Darwin. 2 Central-square, Cambridgeport, Massachusetts, U.S.A.
1872. ‡LEBOUR, G. A., M.A., D.Sc., Professor of Geology in the Armstrong College of Science, Newcastle-on-Tyne.
1910. §Lebour, Miss M. V., M.Sc. Zoological Department, The University, Leeds.
1912. §Lechmere, A. Eckley, M.Sc. Townhope, Hereford.
1895. *Ledger, Rev. Edmund. Protea, Doods-road, Reigate.
1907. ‡Lee, Mrs. Barton. 126 Mile End-lane, Stockport.
1910. *Lee, Ernest. Birkbeck College, Chancery-lane, E.C.
1896. §Lee, Rev. H. J. Barton. 126 Mile End-lane, Stockport.
1909. §Lee, I. L. Care of the Pennsylvania Railroad Company, Broad-street Station, Philadelphia, U.S.A.
1909. ‡Lee, Rev. J. W., D.D. 5068 Washington-avenue, St. Louis, Missouri, U.S.A.
1894. *Lee, Mrs. W. The Nook, Forest Row, Sussex.
1909. ‡Leeming, J. H., M.D. 406 Devon-court, Winnipeg, Canada.
1905. ‡*Lees, Mrs. A. P. Care of Dr. Norris Wolfenden,* 76 *Wimpole-street, W.*
1892. *LEES, CHARLES H., D.Sc., F.R.S., Professor of Physics in the East London College, Mile End. Greenacres, Woodside-road, Woodford Green, Essex.

Year of Election.

1912. ‡Lees, John. Pitscottie, Cupar, Fife.
1886. *Lees, Lawrence W. Old Ivy House, Tettenhall, Wolverhampton.
1906. ‡Lees, Robert. Victoria-street, Fraserburgh.
1889. *Leeson, John Rudd, M.D., C.M., F.L.S., F.G.S. Clifden House, Twickenham, Middlesex.
1906. ‡Leetham, Sidney. Elm Bank, York.
1912. ‡LEGGAT, W. G. Bank of Scotland, Dundee.
1912. §Legge, James G., Municipal Buildings, Liverpool.
1910. §Leigh, H. S. Brentwood, Worsley, near Manchester.
1891. ‡Leigh, W. W. Glyn Bargoed, Treharris, R.S.O., Glamorganshire.
1903. ‡Leighton, G. R., M.D., F.R.S.E. Local Government Board, Edinburgh.
1906. ‡Leiper, Robert T., M.B., F.Z.S. London School of Tropical Medicine, Royal Albert Dock, E.
1905. ‡Leitch, Donald. P.O. Box 1703, Johannesburg.
1913. §Leith, Professor R. F. C. Pathological Laboratory, The University, Birmingham.
1903. *Lempfert, R. G. K., M.A. 66 Sydney-street, S.W.
1908. ‡Lentaigne, John. 42 Merrion-square, Dublin.
1887. *Leon, John T., M.D., B.Sc. 23 Grove-road, Southsea.
1901. §LEONARD, J. H., B.Sc. 31 Gunterstone-road, West Kensington, W.
1913. §Lessing, R., Ph.D. 317 High Holborn, W.C.
1912. *Lessner, C. B., Assoc.M.Inst.C.E., F.C.S. Carril, Spain.
1890. *Lester, Joseph Henry. 5 Grange-drive, Monton Green, Manchester.
1904. *Le Sueur, H. R., D.Sc. Chemical Laboratory, St. Thomas's Hospital, S.E.
1900. ‡Letts, Professor E. A., D.Sc., F.R.S.E. Queen's University, Belfast.
1896. ‡Lever, Sir W. H., Bart. Thornton Manor, Thornton Hough, Cheshire.
1913. §Levick, John. Livingstone House, Livingstone-road, Handsworth, Birmingham.
1887. *Levinstein, Ivan. Hawkesmoor, Fallowfield, Manchester.
1893. *LEWES, VIVIAN B., F.C.S., Professor of Chemistry in the Royal Naval College, Greenwich, S.E.
1904. *Lewis, Mrs. Agnes S., LL.D. Castle Brae, Chesterton-lane, Cambridge.
1870. ‡LEWIS, ALFRED LIONEL. 35 Beddington-gardens, Wallington, Surrey.
1891. ‡Lewis, Professor D. Morgan, M.A. University College, Aberystwyth.
1913. §Lewis, E. O. Gwynfa, Alma-street, Brynmawr.
1899. ‡Lewis, Professor E. P. University of California, Berkeley, U.S.A.
1910. ‡LEWIS, FRANCIS J., D.Sc., F.L.S. Department of Biology, University of Alberta, Edmonton, Alberta, Canada.
1904. ‡Lewis, Hugh. Glanafrau, Newtown, Montgomeryshire.
1910. *Lewis, T. C. West Home, West-road, Cambridge.
1911. §Lewis, W. C. McC., M.A., D.Sc. Professor of Physical Chemistry in the University of Liverpool.
1906. ‡Liddiard, James Edward, F.R.G.S. Rodborough Grange, Bournemouth.
1913. *Lillie, D. G. St. John's College, Cambridge.
1908. ‡Lilly, W. E., M.A., Sc.D. 39 Trinity College, Dublin.
1904. ‡Link, Charles W. 14 Chichester-road, Croydon.
1898. ‡Lippincott, R. C. Cann. Over Court, near Bristol.
1913. *Lishman, G. P., D.Sc., F.I.C. Chemical Laboratory, Lambton Coke Works, Fence Houses, Co. Durham.
1888. ‡LISTER, J. J., M.A., F.R.S. (Pres. D. 1906.) St. John's College, Cambridge.

Year of Election.

1861. *LIVEING, G. D., M.A., F.R.S. (Pres. B, 1882; Council 1888-95; Local Sec. 1862.) Newnham, Cambridge.
1876. *LIVERSIDGE, ARCHIBALD, M.A., F.R.S., F.C.S., F.G.S, F.R.G.S. Fieldhead, George-road, Kingston Hill, Surrey.
1902. §Llewellyn, Evan. Working Men's Institute and Hall, Blaenavon.
1912. §Lloyd, Miss Dorothy Jordan. 16 Ampton-road, Edgbaston, Birmingham.
1909. §Lloyd, George C., Secretary of the Iron and Steel Institute. 28 Victoria-street, S.W.
1903. ‡Lloyd, Godfrey I. H. The University of Toronto, Canada.
1892. ‡LOCH, C. S., D.C.L. Denison House, Vauxhall Bridge-road, S.W.
1905. ‡Lochrane, Miss T. 8 Prince's-gardens, Dowanhill, Glasgow
1904. ‡Lock, Rev. J. B. Herschel House, Cambridge.
1863. ‡LOCKYER, Sir J. NORMAN, K.C.B., LL.D., D.Sc., F.R.S. (PRESIDENT, 1903; Council, 1871-76, 1901-02.) 16 Penywern-road, S.W.
1902. *Lockyer, Lady. 16 Penywern-road, S.W.
1900. §LOCKYER, W. J. S, Ph.D. 16 Penywern-road, S.W.
1886. *LODGE, ALFRED, M.A. (Council, 1913- .) The Croft, Peperharow-road, Godalming.
1875. *LODGE, Sir OLIVER J., D.Sc., LL.D., F.R.S. (PRESIDENT; Pres. A, 1891; Council, 1891-97, 1899-1903, 1912-13), Principal of the University of Birmingham.
1894. *Lodge, Oliver W. F. Mariemont, Edgbaston, Birmingham.
1899. §Loncq, Emile. 6 Rue de la Plaine, Laon, Aisne, France.
1902. ‡LONDONDERRY, The Marquess of, K.G. Londonderry House, Park-lane, W.
1903. ‡Long, Frederick. The Close, Norwich.
1905. ‡Long, W. F. City Engineer's Office, Cape Town.
1883. *Long, William. Thelwall Heys, near Warrington.
1910. *Londgen, G. A. Stanton-by-Dale, Nottingham.
1904. *Longden, J. A., M.Inst.C.E. Chislehurst, Marlborough-road, Bournemouth.
1898. *Longfield, Miss Gertrude. Belmont, High Halstow, Rochester.
1901. *Longstaff, Captain Frederick V., F.R.G.S. No. 1252 Post Office, Victoria, B.C., Canada.
1875. *Longstaff, George Blundell, M.A., M.D., F.C.S., F.S.S. Highlands, Putney Heath, S.W.
1872. *Longstaff, Lieut.-Colonel Llewellyn Wood, F.R.G.S. Ridgelands, Wimbledon, S.W.
1881. *Longstaff, Mrs. Ll. W. Ridgelands, Wimbledon, S.W.
1899. *Longstaff, Tom G., M.A., M.D. Picket Hill, Ringwood.
1903. ‡*Loton, John, M.A. 23 Hawkshead-street, Southport.*
1897. ‡LOUDON, JAMES, LL.D., President of the University of Toronto, Canada.
1883. *LOUIS, D. A., F.G.S., F.I.C. 123 Pall Mall, S.W.
1896. ‡Louis, Henry, D.Sc., Professor of Mining in the Armstrong College of Science, Newcastle-on-Tyne.
1887. *LOVE, A. E. H., M.A., D.Sc., F.R.S. (Pres. A, 1907), Professor of Natural Philosophy in the University of Oxford. 34 St. Margaret's-road, Oxford.
1886. *Love, E. F. J., M.A, D.Sc. The University, Melbourne, Australia.
1904. *Love, J. B., LL.D. Outlands, Devonport.
1876. *Love, James, F.R.A.S., F.G.S., F.Z.S. 33 Clanricarde-gardens, W.
1908. §Low, Alexander, M.A., M.D. The University, Aberdeen.
1909. ‡Low, David, M.D. 1927 Scarth-street, Regina, Saskatchewan, Canada.
1912. ‡Low, William. Balmakewan, Seaview, Monifieth.

Year of Election.

1885. §Lowdell, Sydney Poole. Baldwin's Hill, East Grinstead, Sussex.
1891. §Lowdon, John. St. Hilda's, Barry, Glamorgan.
1885. *Lowe, Arthur C. W. Gosfield Hall, Halstead, Essex.
1886. *Lowe, John Landor, B.Sc., M.Inst.C.E. Spondon, Derbyshire.
1894. ‡Lowenthal, Miss Nellie. Woodside, Egerton, Huddersfield.
1903. *Lowry, Dr. T. Martin. 130 Horseferry-road, S.W.
1913. §Lucas, Sir Charles P., K.C.B., K.C.M.G. 65 St. George's-square, S.W.
1913. §Lucas, Harry. Hilver, St. Agnes-road, Moseley, Birmingham.
1901. *Lucas, Keith, F.R.S. Trinity College, Cambridge.
1891. *Lucovich, Count A. Tyn-y-parc, Whitchurch, near Cardiff.
1906. §Ludlam, Ernest Bowman. College Gate, 32 College-road, Clifton, Bristol.
1866 *Lund, Charles. Ilkley, Yorkshire.
1883. *Lupton, Arnold, M.P., M.Inst.C.E., F.G.S. 7 Victoria-street, S.W.
1874. *Lupton, Sydney, M.A. (Local Sec. 1890.) 102 Park-street, Grosvenor-square, W.
1898. ‡Luxmoore, Dr. C. M., F.I.C., 19 Disraeli-gardens, Putney, S.W.
1903. ‡Lyddon, Ernest H. Lisvane, near Cardiff.
1871. ‡Lyell, Sir Leonard, Bart., F.G.S. Kennordy, Kirriemuir.
1884 ‡Lyman, H. H. 384 St Paul-street, Montreal, Canada
1912. *Lynch, Arthur, M.A., M.P. 80 Antrim-mansions, Haverstock Hill, N.W.
1907. *Lyons, Captain Henry George, D.Sc., F.R.S. (Council, 1912- .) 5 Heathview-gardens, Roehampton, S.W.
1908. ‡Lyster, George H. 34 Dawson-street, Dublin.
1908. ‡Lyster, Thomas W., M.A. National Library of Ireland, Kildare-street, Dublin.

1905. ‡Maberly, Dr. John. Shirley House, Woodstock, Cape Colony.
1868. ‡Macalister, Alexander, M.A., M.D., F.R.S. (Pres H, 1892; Council, 1901-06), Professor of Anatomy in the University of Cambridge. Torrisdale, Cambridge.
1878. ‡MacAlister, Sir Donald, K.C.B., M.A., M.D., LL.D., B.Sc., Principal of the University of Glasgow.
1904. ‡Macalister, Miss M. A. M. Torrisdale, Cambridge.
1908. ‡Macallan, J., F.I.C., F.R.S.E. 3 Rutland-terrace, Clontarf, Co. Dublin.
1896. ‡Macallum, Professor A. B., Ph.D., D.Sc., F.R.S. (Pres. I, 1910; Local Sec. 1897.) 59 St. George-street, Toronto, Canada.
1879. §MacAndrew, James J., F.L.S. Lukesland, Ivybridge, South Devon.
1883. ‡MacAndrew, Mrs. J. J. Lukesland, Ivybridge, South Devon.
1909. ‡MacArthur, J. A., M.D. Canada Life Building, Winnipeg, Canada.
1896. *Macaulay, F. S., M.A. The Chesters, Vicarage-road, East Sheen, S.W.
1904. *Macaulay, W. H. King's College, Cambridge.
1896. ‡MacBride, E. W., M.A., D.Sc., F.R.S., Professor of Zoology in the Imperial College of Science and Technology, S.W.
1902. *Maccall, W. T., M.Sc. Technical College, Sunderland.
1912. §McCallum, George Fisher. 142 St. Vincent-street, Glasgow.
1912. §McCallum, Mrs. Lizzie. 142 St. Vincent-street, Glasgow.
1886. ‡MacCarthy, Rev. E. F. M., M.A. 50 Harborne-road, Edgbaston, Birmingham.
1908. §McCarthy, Edward Valentine, J.P. Ardmanagh House, Glenbrook, Co. Cork.
1909. ‡McCarthy, J. H. Public Library, Winnipeg, Canada.
1884. *McCarthy, J. J., M.D. 11 Wellington-road, Dublin.

Year of Election.

1887. *McCarthy, James. 1 Sydney-place, Bath.
1904. §McClean, Frank Kennedy. Rusthall House, Tunbridge Wells.
1902. ‡McClelland, J. A., M.A., F.R.S., Professor of Physics in University College, Dublin.
1906. ‡McClure, Rev. E. 80 Eccleston-square, S.W.
1878. *M'Comas, Henry. 12 Elgin-road, Dublin.
1908. §McCombie, Hamilton, M.A., Ph.D. The University, Birmingham.
1901. *MacConkey, Alfred. Lister Lodge, Elstree, Herts.
1901. ‡McCrae, John, Ph.D. 7 Kirklee-gardens, Glasgow.
1912. ‡MacCulloch, Rev. Canon J. A., D.D. The Rectory, Bridge of Allan.
1905 §McCulloch, Principal J. D. Free College, Edinburgh.
1904. ‡McCulloch, Major T., R.A. 68 Victoria-street, S.W.
1909. ‡MacDonald, Miss Eleanor. Fort Qu'Appelle, Saskatchewan, Canada.
1904. ‡MACDONALD, H. M., M.A., F.R.S., Professor of Mathematics in the University of Aberdeen.
1905. ‡McDonald, J. G. P.O. Box 67, Bulawayo.
1900. ‡MacDonald, J. Ramsay, M.P. 3 Lincoln's Inn-fields, W.C.
1905. §MACDONALD, J. S., B.A. (Pres. I, 1911), Professor of Physiology in the University of Sheffield.
1884. *Macdonald, Sir W. C. 449 Sherbrooke-street West, Montreal, Canada
1909. ‡MacDonell, John, M.D. Portage-avenue, Winnipeg Canada.
1909. *MacDougall, R. Stewart. The University, Edinburgh.
1912. §McDougall, Dr. W., F.R.S. Woodsend, Foxcombe Hill, near Oxford.
1908. ‡McEwen, Walter, J.P. Flowerbank, Newton Stewart, Scotland.
1906. §McFarlane, John, M.A. 30 Parsonage-road, Withington, Manchester.
1885. ‡Macfarlane, J. M., D.Sc., F.R.S.E., Professor of Biology in the University of Pennsylvania, Lansdowne, Delaware Co., Pennsylvania, U.S.A.
1901. ‡Macfee, John. 5 Greenlaw-terrace, Paisley.
1909. ‡Macgachen, A. F. D. 281 River-avenue, Winnipeg, Canada.
1888. ‡MacGeorge, James. 8 Matheson-road, Kensington, W.
1908. ‡McGRATH, Sir JOSEPH, LL.D. (Local Sec. 1908.) Royal University of Ireland, Dublin.
1908. §McGregor, Charles. Training Centre, Charlotte-street, Aberdeen
1906. ‡MACGREGOR, D. H., M.A. Trinity College, Cambridge.
1902. ‡*McIlroy, Archibald. Glenvale, Drumbo, Lisburn, Ireland.*
1867. *McINTOSH, W. C., M.D., LL.D., F.R.S., F.R.S.E., F.L.S. (Pres. D, 1885), Professor of Natural History in the University of St. Andrews. 2 Abbotsford-crescent, St. Andrews, N.B.
1909. ‡McIntyre, Alexander. 142 Maryland-avenue, Winnipeg, Canada.
1909. ‡McIntyre, Daniel. School Board Offices, Winnipeg, Canada.
1912. §McIntyre, J. Lewis, M.A., D.Sc. Abbotsville, Cults, Aberdeenshire.
1909. ‡McIntyre, W. A. 339 Kennedy-street, Winnipeg, Canada.
1884. §MacKay, A. H., B.Sc., LL.D., Superintendent of Education. Education Office, Halifax, Nova Scotia, Canada.
1913. *Mackay, John. 85 Bay-street, Toronto, Canada.
1885. ‡MACKAY, JOHN YULE, M.D., LL.D., Principal of and Professor of Anatomy in University College, Dundee.
1912. §Mackay, R. J. 27 Arkwright-road, Hampstead, N.W.
1908. ‡McKay, William, J.P. Clifford-chambers, York.
1909. §McKee, Dr. E. S. Grand and Nassau-streets, Cincinnati, U.S.A.
1873. ‡McKENDRICK, JOHN G., M.D., LL.D., F.R.S., F.R.S.E. (Pres. I, 1901; Council, 1903-09), Emeritus Professor of Physiology in the University of Glasgow. Maxieburn, Stonehaven, N.B.

Year of Election.

1909. ‡McKenty, D. E. 104 Colony-street, Winnipeg, Canada.
1907. ‡McKenzie, Alexander, M.A., D.Sc., Ph.D. Birkbeck College, Chancery-lane, W.C.
1905. ‡Mackenzie, Hector. Standard Bank of South Africa, Cape Town.
1897. ‡McKenzie, John J. 61 Madison-avenue, Toronto, Canada.
1910. ‡Mackenzie, K. J. J., M.A. 10 Richmond-road, Cambridge.
1909. §MacKenzie, Kenneth. Royal Alexandra Hotel, Winnipeg, Canada.
1901. *Mackenzie, Thomas Brown. Netherby, Manse-road, Motherwell, N.B.
1912. §Mackenzie, William, J.P. 22 Meadowside, Dundee.
1872. *Mackey, J. A. United University Club, Pall Mall East, S.W.
1901. ‡Mackie, William, M.D. 13 North-street, Elgin.
1887. ‡Mackinder, H. J., M.A., M.P., F.R.G.S. (Pres. E, 1895; Council, 1904–1905.) 25 Cadogan-gardens, S.W.
1911. ‡Mackinnon, Miss D. L. University College, Dundee.
1893. *McLaren, Mrs. E. L. Colby, M.B., Ch.B. 137 Tettenhall-road, Wolverhampton.
1901. ‡Maclaren, J. Malcolm. Royal Colonial Institute, Northumberland Avenue, W.C.
1913. §McLaren, S. B. University College, Reading.
1901. ‡Maclay, William. Thornwood, Langside, Glasgow.
1901. ‡McLean, Angus, B.Sc. Harvale, Meikleriggs, Paisley.
1892. *Maclean, Magnus, M.A., D.Sc., F.R.S.E. (Local Sec. 1901), Professor of Electrical Engineering, Technical College, Glasgow.
1912. §McLean, R. C., B.Sc. 36 Avenue-road, Highgate, N.
1908. §McLennan, J. C., Professor of Physics in the University of Toronto, Canada.
1868. §McLeod, Herbert, LL.D., F.R.S. (Pres. B, 1892; Council, 1885–90.) 37 Montague-road, Richmond, Surrey.
1909. ‡MacLeod, M. H. C.N.R. Depôt, Winnipeg, Canada.
1883. ‡MacMahon, Major Percy A., D.Sc., LL.D., F.R.S. (Trustee, 1913– ; General Secretary, 1902–13; Pres. A, 1901; Council, 1898–1902.) 27 Evelyn-mansions, Carlisle-place, S.W.
1909. ‡McMillan, The Hon. Sir Daniel H., K.C.M.G. Government House, Winnipeg, Canada.
1902. ‡McMordie, Robert J. Cabin Hill, Knock, Co. Down.
1878. ‡Macnie, George. 59 Bolton-street, Dublin.
1905. §Macphail, Dr. S. Rutherford. Rowditch, Derby.
1909. ‡MacPhail, W. M. P.O. Box 88, Winnipeg, Canada.
1907. ‡Macrosty, Henry W. 29 Hervey-road, Blackheath, S.E.
1906. ‡Macturk, G. W. B. 15 Bowlalley-lane, Hull.
1908. ‡McVittie, R. B., M.D. 62 Fitzwilliam-square North, Dublin.
1908. ‡McWalter, J. C., M.D., M.A. 19 North Earl-street, Dublin.
1902. ‡McWeeney, Professor E. J., M.D. 84 St. Stephen's-green, Dublin.
1910. ‡McWilliam, Dr. Andrew. Kalimate, B.N.R., near Calcutta.
1908. ‡Madden, Rt. Hon. Mr. Justice. Nutley, Booterstown, Dublin.
1905. ‡Magenis, Lady Louisa. 34 Lennox-gardens, S.W.
1909. ‡Magnus, Laurie, M.A. 12 Westbourne-terrace, W.
1875. *Magnus, Sir Philip, B.Sc., B.A., M.P. (Pres. L, 1907). 16 Gloucester-terrace, Hyde Park, W.
1908. *Magson, Egbert H. Westminster College, Horseferry-road, S.W.
1907. *Mair, David. Civil Service Commission, Burlington-gardens, W.
1902. *Mairet, Mrs. Ethel M. The Thatched House, Shottery, Stratford-on-Avon.
1913. §Maitland, T. Gwynne, M.D. The University, Edmund-street, Birmingham.

Year of Election.

1908. *Makower, W. The University, Manchester.
1914. §Malinowski, B. London School of Economics, Clare Market, W.C.
1912. ‡Malloch, James, M.A., F.S.A. (Scot.) Training College, Dundee.
1905. ‡Maltby, Lieutenant G. R., R.N. 54 St. George's-square, S.W.
1897. ‡Mance, Sir H. C. Old Woodbury, Sandy, Bedfordshire.
1903. ‡Manifold, C. C. 16 St. James's-square, S.W.
1894. ‡Manning, Percy, M.A., F.S.A. Watford, Herts.
1887. *March, Henry Colley, M.D., F.S.A. Portesham, Dorchester, Dorsetshire.
1902. *Marchant, Dr. E. W. The University, Liverpool.
1912. §Marchant, Rev. James, F.R.S.E. 42 Great Russell-street, W.C.
1898. *Mardon, Heber. 2 Litfield-place, Clifton, Bristol.
1911. *Marett, R. R. Exeter College, Oxford.
1900. ‡Margerison, Samuel. Calverley Lodge, near Leeds.
1864. ‡Markham, Sir Clements R., K.C.B., F.R.S., F.R.G.S., F.S.A. (Pres. E, 1879; Council, 1893–96.) 21 Eccleston-square, S.W.
1905. §Marks, Samuel. P.O. Box 379, Pretoria.
1905. ‡Marloth, R., M.A., Ph.D. P.O. Box 359, Cape Town.
1881. *Marr, J. E., M.A., D.Sc., F.R.S., F.G.S. (Pres. C, 1896; Council, 1896–1902, 1910– .) St. John's College, Cambridge.
1903. ‡Marriott, William. Royal Meteorological Society, 70 Victoria-street, S.W.
1892. *Marsden-Smedley, J. B. Lea Green, Cromford, Derbyshire.
1883. *Marsh, Henry Carpenter. 3 Lower James-street, Golden-square, W.
1887. ‡Marsh, J. E., M.A., F.R.S. University Museum, Oxford.
1889. *Marshall, Alfred, M.A., LL.D., D.Sc. (Pres. F, 1890.) Balliol Croft, Madingley-road, Cambridge.
1912. ‡Marshall, Professor C. R., M.A., M.D. The Medical School, Dundee.
1904. ‡Marshall, F. H. A. University of Edinburgh.
1905. ‡Marshall, G. A. K. 6 Chester-place, Hyde Park-square, W.
1901. ‡*Marshall, Robert.* 97 *Wellington-street, Glasgow.*
1907. ‡Marston, Robert. 14 Ashleigh-road, Leicester.
1899. §Martin, Miss A. M. Park View, 32 Bayham-road, Sevenoaks.
1911. §Martin, Professor Charles James, M.B., D.Sc., F.R.S., Director of the Lister Institute, Chelsea-gardens, S.W.
1884. §Martin, N. H., J.P., F.R.S.E., F.L.S. Ravenswood, Low Fell, Gateshead.
1889. *Martin, Thomas Henry, Assoc.M.Inst.C.E. Windermere, Mount Pleasant-road, Hastings.
1912. ‡Martin, W. H. Blyth, (Local Sec. 1912.) City Chambers, Dundee.
1911. §Martindell, E. W., M.A. Royal Anthropological Institute, 50 Great Russell-street, W.C.
1913. §Martineau, Lieut.-Colonel Ernest, V.D. Ellerslie, Augustus-road, Edgbaston, Birmingham.
1913. §Martineau, P. E. The White House, Wake Green-road, Moseley, Birmingham.
1907. ‡Masefield, J. R. B., M.A. Rosehill, Cheadle, Staffordshire.
1905. *Mason, Justice A. W. Supreme Court, Pretoria.
1913. *Mason, Edmund W., B.A. 2 York-road, Edgbaston, Birmingham.
1893. *Mason, Thomas. Enderleigh, Alexandra Park, Nottingham.
1913. §Mason, William. Engineering Laboratory, The University, Liverpool.
1891. *Massey, William H., M.Inst.C.E. Twyford, R.S.O., Berkshire.

Year of
Election.

1885. ‡Masson, David Orme, D.Sc., F.R.S., Professor of Chemistry in the University of Melbourne.
1910. ‡Masson, Irvine, M.Sc. 11 Chester-street, Edinburgh.
1905. §Massy, Miss Mary. 2 Duke-street, Bath.
1901. *Mather, G. R. Boxlea, Wellingborough.
1910. *Mather, Thomas, F.R.S., Professor of Electrical Engineering in the City and Guilds of London Institute, Exhibition-road, S.W.
1887. *Mather, Right Hon. Sir William, M.Inst.C.E. Salford Iron Works, Manchester.
1909. ‡Mathers, Mr. Justice. 16 Edmonton-street, Winnipeg, Canada.
1908. ‡Matheson, Sir R. E., LL.D. Charlemont House, Rutland-square, Dublin.
1894. ‡Mathews, G. B., M.A., F.R.S. 10 Menai View, Bangor, North Wales.
1902. ‡Matley, C. A., D.Sc. Military Accounts Department, Naina Tal, U.P., India.
1904. ‡Matthews, D. J. The Laboratory, Citadel Hill, Plymouth.
1899. *Maufe, Herbert B., B.A., F.G.S. P.O. Box 168, Bulawayo, Rhodesia.
1893. ‡Mavor, Professor James. University of Toronto, Canada.
1894. §Maxim, Sir Hiram S., Thurlow Park, Norwood-road, West Norwood, S.E.
1905. §Maylard, A. Ernest. 12 Blythswood-square, Glasgow.
1905. ‡Maylard, Mrs. 12 Blythswood-square, Glasgow.
1878. *Mayne, Thomas. 19 Lord Edward-street, Dublin.
1904. ‡Mayo, Rev. J., LL.D. 6 Warkworth-terrace, Cambridge.
1912. ‡Meek, Alexander, M.Sc., Professor of Zoology in the Armstrong College of Science, Newcastle-on-Tyne.
1913. §Megson, A. L. The Elms, Vale-road, Bowdon.
1879. §Meiklejohn, John W. S., M.D. 105 Holland-road, W.
1905. ‡Mein, W. W. P.O. Box 1145, Johannesburg.
1881. *Meldola, Raphael, D.Sc., LL.D., F.R.S., F.C.S., F.I.C., F.R.A.S., F.E.S., Officier de l'Instr. Publ. France (Pres. B, 1895; Council, 1892–99, 1911–), Professor of Chemistry in the Finsbury Technical College, City and Guilds of London Institute. 6 Brunswick-square, W.C.
1908. ‡Meldrum, A. N., D.Sc. Chemical Department, The University, Manchester.
1883. ‡Mellis, Rev. James. 23 Part-street. Southport.
1879. *Mellish, Henry. Hodsock Priory, Worksop.
1866. ‡Mello, Rev. J. M., M.A., F.G.S. Cliff Hill, Warwick.
1881. §Melrose, James. Clifton Croft, York.
1905. *Melvill, E. H. V., F.G.S., F.R.G.S. P.O. Val, Standerton District, Transvaal.
1913. *Mentz-Tolley, Richard. Moseley Court, near Wolverhampton.
1909. ‡Menzies, Rev. James, M.D. Hwaichingfu, Honan, China.
1905. ‡Meredith, H. O., M.A., Professor of Economics in Queen's University, Belfast. 55 Bryansburn-road, Bangor, Co. Down.
1879. ‡Merivale, John Herman, M.A. (Local Sec. 1889.) Togston Hall, Acklington.
1899. *Merrett, William H., F.I.C. Hatherley, Grosvenor-road. Wallington, Surrey.
1899. ‡Merryweather, J. C. 4 Whitehall-court, S.W.
1884. *Merthyr, The Right Hon. Lord, K.C.V.O. The Mardy, Aberdare.
1889. *Merz, John Theodore. The Quarries, Newcastle-upon-Tyne.
1905. ‡Methven, Cathcart W. Club Arcade, Smith-street, Durban.

Year of Election.

1896. §Metzler, W. H., Ph.D., Professor of Mathematics in Syracuse University, Syracuse, New York, U.S.A.
1869. ‡MIALL, LOUIS C., D.Sc., F.R.S., F.L.S., F.G.S. (Pres. D, 1897; Pres. L, 1908; Local Sec. 1890.) Norton Way North, Letchworth.
1903. *Micklethwait, Miss Frances M. G. 15 St. Mary's-square, Paddington, W.
1912. §Middlemore, Thomas, B.A. Melsetter, Orkney.
1881. *Middlesbrough, The Right Rev. Richard Lacy, D.D., Bishop of Bishop's House, Middlesbrough.
1904. ‡MIDDLETON, T. H., C.B., M.A. (Pres. M, 1912.) Board of Agriculture and Fisheries, 4 Whitehall-place, S.W.
1894. *MIERS, Sir H. A., M.A., D.Sc., F.R.S., F.G.S. (Pres. C, 1905; Pres. L, 1910), Principal of the University of London. 23 Wetherby-gardens, S.W.
1885. ‡MILL, HUGH ROBERT, D.Sc., LL.D., F.R.S.E., F.R.G.S. (Pres. E, 1901.) 62 Camden-square, N.W.
1905. ‡Mill, Mrs. H. R. 62 Camden-square, N.W.
1912. ‡MILLAR, Dr. A. H. (Local Sec. 1912.) Albert Institute, Dundee.
1889 *MILLAR, ROBERT COCKBURN. 30 York-place, Edinburgh.
1909. §Miller, A. P. Quibell, Ontario, Canada.
1897. *Miller, G. Willet, Provincial Geologist. Provincial Geologist's Office, Toronto, Canada.
1895. ‡Miller, Thomas, M.Inst.C.E. 9 Thoroughfare, Ipswich.
1904. ‡Millis, C. T. Hollydene, Wimbledon Park-road, Wimbledon.
1905. §Mills, Mrs. A. A. Ceylon Villa, Blinco-grove, Cambridge.
1908. ‡Mills, Miss E. A. Nurney, Glenagarey, Co. Dublin.
1868. *MILLS, EDMUND J., D.Sc., F.R.S., F.C.S. 64 Twyford-avenue, West Acton, W.
1908. §Mills, Miss Gertrude Isabel. Nurney, Glenagarey, Co. Dublin.
1908. §Mills, John Arthur, M.B. Durham County Asylum, Winterton, Ferryhill.
1908. §Mills, W. H., M.Inst.C.E. Nurney, Glenagarey, Co. Dublin.
1902. ‡Mills, W. Sloan, M.A. Vine Cottage, Donaghmore, Newry.
1907. ‡Milne, A., M.A. University School, Hastings.
1910. §Milne, J. B. Cross Grove House, Totley, near Sheffield.
1910. *Milne, James Robert, D.Sc., F.R.S.E. 11 Melville-crescent, Edinburgh.
1903. *Milne, R. M. Royal Naval College, Dartmouth, South Devon.
1898. *MILNER, S. ROSLINGTON, D.Sc. The University, Sheffield.
1908. §Milroy, T. H., M.D., Dunville Professor of Physiology in Queen's University, Belfast.
1907. §MILTON, J. H., F.G.S., F.L.S., F.R.G.S., 8 College-avenue, Crosby, Liverpool.
1912. §Minchin, E. A., M.A., F.R.S., Professor of Protozoology in the University of London. 53 Cheyne-court, Chelsea, S.W.
1914. §Minchin, Mrs., 53 Cheyne-court, Chelsea, S.W.
1880. ‡MINCHIN, G. M., M.A., F.R.S. 149 Banbury-road, Oxford.
1901. *Mitchell, Andrew Acworth. 7 Huntly-gardens, Glasgow.
1913. *Mitchell, Francis W. V. 25 Augustus-road, Edgbaston, Birmingham.
1901. *Mitchell, G. A. 5 West Regent-street, Glasgow.
1909. ‡Mitchell, J. F. 211 Rupert-street, Winnipeg, Canada.
1885. ‡MITCHELL, P. CHALMERS, M.A., D.Sc., F.R.S., Sec.Z.S. (Pres. D, 1912; Council, 1906–13.) Zoological Society, Regent's Park, N.W.
1908. ‡Mitchell, W. M. 2 St. Stephen's Green, Dublin.

Year of Election

1905. *Mitchell, W. E. C. Box 129, Johannesburg.
1895. *Moat, William, M.A. Johnson Hall, Eccleshall, Staffordshire.
1908. ‡Moffat, C. B. 36 Hardwicke-street, Dublin.
1905. ‡Moir, James, D.Sc. Mines Department, Johannesburg.
1905. §Molengraaff, Professor G. A. F. Voorstreat 60, Delft, The Hague.
1883. ‡Mollison, W. L., M.A. Clare College, Cambridge.
1900. *MONCKTON, H. W., Treas. L.S., F.G.S. 3 Harcourt-buildings, Temple, E.C.
1905. *MONCRIEFF, Colonel Sir C. SCOTT, G.C.S.I., K.C.M.G., R.E. (Pres. G, 1905.) 11 Cheyne-walk, S.W.
1905. ‡Moncrieff, Lady Scott. 11 Cheyne-walk, S.W.
1891. *Mond, Robert Ludwig, M.A., F.R.S.E., F.G.S. 20 Avenue-road, Regent's Park, N.W.
1909. ‡Moody, A. W., M.D. 432½ Main-street, Winnipeg, Canada.
1909. *MOODY, G. T., D.Sc. Lorne House, Dulwich, S.E.
1912. §MOORE, BENJAMIN, D.Sc., F.R.S., Professor of Bio-Chemistry in the University of Liverpool. 84 Shrewsbury-road, Birkenhead.
1911. §Moore, E. S., Professor of Geology and Mineralogy in the School of Mines, Pennsylvania State College, Pennsylvania, U.S.A.
1908. *MOORE, Sir F. W. Royal Botanic Gardens, Glasnevin, Dublin.
1894. ‡Moore, Harold E. Oaklands, The Avenue, Beckenham, Kent.
1908. ‡Moore, Sir John W., M.D. 40 Fitzwilliam-square West, Dublin
1901. *Moore, Robert T. 142 St. Vincent-street, Glasgow.
1905. ‡Moore, T. H. Thornhill Villa, Marsh, Huddersfield.
1892. ‡Moray, The Right Hon. the Earl of, F.G.S. Kinfauns Castle, Perth.
1912. ‡Moray, The Countess of. Kinfauns Castle, Perth.
1896. *MORDEY, W. M. 82 Victoria-street, S.W.
1901. *Moreno, Francisco P. Paraná 915, Buenos Aires.
1905. *Morgan, Miss Annie. Friedrichstrasse No. 2, Vienna.
1895. ‡MORGAN, C. LLOYD, F.R.S., F.G.S., Professor of Psychology in the University of Bristol.
1902. ‡MORGAN, GILBERT T., D.Sc., F.I.C., Professor of Chemistry in the Royal College of Science, Dublin.
1902. *Morgan, Septimus Vaughan. 37 Harrington-gardens, S.W.
1901. *Morison, James. Perth.
1883. *MORLEY, HENRY FORSTER, M.A., D.Sc., F.C.S. 5 Lyndhurst-road, Hampstead, N.W.
1906. ‡Morrell, H. R. Scarcroft-road, York.
1896. *Morrell, Dr. R. S. Tor Lodge, Tettenhall Wood, Wolverhampton.
1892. ‡MORRIS, Sir DANIEL, K.C.M.G., D.Sc., F.L.S. 14 Crabton-close, Boscombe, Hants.
1896. *Morris, J. T. 36 Cumberland-mansions, Seymour-place, W.
1880. §Morris, James. 23 Brynymor Cresent, Swansea.
1907. ‡Morris, Colonel Sir W. G., K.C.M.G. Care of Messrs. Cox & Co., 16 Charing Cross, W.C.
1899. *MORROW, JOHN, M.Sc., D.Eng. Armstrong College, Newcastle-upon-Tyne.
1909. ‡Morse, Morton F. Wellington-crescent, Winnipeg, Canada.
1886. *Morton, P. F. 15 Ashley-place, Westminster, S.W.
1896. *MORTON, WILLIAM B., M.A., Professor of Natural Philosophy in Queen's University, Belfast.
1913. *Moseley, Henry Gwyn-Jeffreys. 48 Woodstock-road, Oxford.
1913. §Mosely, Alfred. West Lodge, Barnet.
1908. ‡Moss, Dr. C. E. Botany School, Cambridge.
1912. §Moss, Mrs. 154 Chesterton-road, Cambridge.
1876. §Moss, RICHARD JACKSON, F.I.C., M.R.I.A. Royal Dublin Society, and St. Aubyn's, Ballybrack, Co. Dublin.

Year of
Election.

1892. *Mostyn, S. G., M.A., M.B. Health Office, Houndgate, Darlington.
1913. §Mott, Dr. F. W., F.R.S. 25 Nottingham-place, W.
1913. §Mottram, V. H. 256 Lordship-lane, East Dulwich, S.E.
1912. *Moulton, J. C. Sarawak Museum, Sarawak.
1878. *MOULTON, The Right Hon. Lord Justice, M.A., K.C., F.R.S. 57 Onslow-square, S.W.
1899 §Mowll, Martyn. Chaldercot, Leyburne-road, Dover.
1905. ‡Moylan, Miss V. C. 3 Canning-place, Palace Gate, W.
1905. *Moysey, Miss E. L. Pitcroft, Guildford, Surrey.
1911. *Moysey, Lewis, B.A., M.B. St. Moritz, Ilkeston-road, Nottingham.
1912. ‡Mudie, Robert Francis. 6 Fintry-place, Broughty Ferry.
1902. §Muir, Arthur H. 7 Donegall-square West, Belfast.
1907. *Muir, Professor James. 31 Burnbank-gardens, Glasgow.
1874 ‡MUIR, M. M. PATTISON, M.A. Hillcrest, Farnham, Surrey.
1909. ‡Muir, Robert R. Grain Exchange-building, Winnipeg, Canada.
1912. §Muir, Thomas Scott. 19 Seton-place, Edinburgh.
1904. §Muir, William, I.S.O. Rowallan, Newton Stewart, N.B.
1872. *MUIRHEAD, ALEXANDER, D.Sc., F.R.S., F.C.S. 12 Carteret-street, Queen Anne's Gate, Westminster, S.W.
1913. §Muirhead, Professor J. H. The Rowans, Balsall Common, near Coventry.
1905. *Muirhead, James M. P., F.R.S.E. Royal Automobile Club, Pall Mall, S.W.
1876. *Muirhead, Robert Franklin, B.A., D.Sc. 64 Great George-street, Hillhead, Glasgow.
1902. ‡Mullan, James. Castlerock, Co. Derry.
1884. *MÜLLER, HUGO, Ph.D., F.R S., F.C.S. 13 Park-square East, Regent's Park, N.W.
1908. ‡MULLIGAN, JOHN. (Local Sec. 1908.) Greinan, Adelaide-road, Kingstown, Co. Dublin.
1904. ‡Mullinger, J. Bass, M.A. 1 Bene't-place, Cambridge.
1911. ‡Mumby, Dr. B. H. Borough Asylum, Milton, Portsmouth.
1898. ‡Mumford, C. E. Cross Roads House, Bouverie-road, Folkestone.
1901. *Munby, Alan E. 44 Downshire-hill, Hampstead, N.W.
1906. ‡Munby, Frederick J. Whixley, York.
1904. ‡Munro, A. Queen's College, Cambridge.
1909. ‡Munro, George. 188 Roslyn-road, Winnipeg, Canada.
1883. *MUNRO, ROBERT, M.A., M.D., LL.D. (Pres. H, 1893.) Elmbank, Largs, Ayrshire, N.B.
1909. ‡Munson, J. H., K.C. Wellington-crescent, Winnipeg, Canada.
1911. ‡*Murdoch, W. H. F., B.Sc.* 14 *Howitt-road, Hampstead, N.W.*
1909. §Murphy, A. J. Vanguard Manufacturing Co., Dorrington-street, Leeds.
1908. ‡Murphy, Leonard. 156 Richmond-road, Dublin.
1908. ‡MURPHY, WILLIAM M., J.P. Dartry, Dublin.
1905 ‡Murray, Charles F. K., M.D. Kenilworth House, Kenilworth, Cape Colony.
1905. §Murray, Sir James, LL.D., Litt.D. Sunnyside, Oxford.
1905. §Murray, Lady. Sunnyside, Oxford.
1884. ‡MURRAY, Sir JOHN, K.C.B., LL.D., D.Sc., Ph.D., F.R.S., F.R.S.E. (Pres. E, 1899.) Challenger Lodge, Wardie, Edinburgh.
1903. §Murray, Colonel J. D. Rowbottom-square, Wigan.
1892. ‡Murray, T. S., D.Sc. 27 Shamrock-street, Dundee.
1909. ‡Murray, W. C. University of Saskatchewan, Saskatoon, Saskatchewan, Canada.
1906. ‡Musgrove, Mrs. Edith M. S., D.Sc. The Woodlands, Silverdale, Lancashire.

Year of
Election.

1912. *Musgrove, James, M.D., Professor of Anatomy in the University of St. Andrews.
1870. *Muspratt, Edward Knowles. Seaforth Hall, near Liverpool.
1906. ‡Myddelton-Gavey, E. H., J.P., F.R.G.S. Stanton Prior, Meads, Eastbourne.
1913. §Myddelton-Gavey, Miss Violet. Stanton Prior, Meads, Eastbourne.
1902. ‡Myddleton, Alfred. 62 Duncairn-street, Belfast.
1902. *Myers, Charles S., M.A., M.D. Great Shelford, Cambridge.
1909. *Myers, Henry. The Long House, Leatherhead.
1906. ‡Myers, Jesse A. Glengarth, Walker-road, Harrogate.
1890, *Myres, John L., M.A., F.S.A. (Pres. H, 1909; Council, 1909–), Wykeham Professor of Ancient History in the University of Oxford. 101 Banbury-road, Oxford.

1886. ‡Nagel, D. H., M.A. (Local Sec. 1894.) Trinity College, Oxford.
1892. *Nairn, Sir Michael B., Bart. Kirkcaldy, N.B.
1890. †Nalder, Francis Henry. 34 Queen-street, E.C.
1908. ‡Nally, T. H. Temple Hill, Terenure, Co. Dublin.
1872. ‡Nares, Admiral Sir G. S., K.C.B., R.N., F.R.S., F.R.G.S. 7 The Crescent, Surbiton.
1909. ‡Neild, Frederic, M.D. Mount Pleasant House, Tunbridge Wells.
1883. *Neild, Theodore, M.A. Grange Court, Leominster.
1898. *Nevill, Rev. J. H. N., M.A. The Vicarage, Stoke Gabriel, South Devon.
1866. *Nevill, The Right Rev. Samuel Tarratt, D.D., F.L.S., Bishop of Dunedin, New Zealand.
1889. ‡Neville, F. H., M.A., F.R.S. Sidney College, Cambridge.
1889. *Newall, H. Frank, M.A., F.R.S., F.R.A.S., Professor of Astrophysics in the University of Cambridge. Madingley Rise, Cambridge.
1912. §Newberry, Percy E., M.A., Professor of Egyptology in the University of Liverpool. Oldbury Place, Ightham, Kent.
1901. ‡Newbigin, Miss Marion, D.Sc. Royal Scottish Geographical Society, Edinburgh.
1901. ‡Newman, F. H. Tullie House, Carlisle.
1913. §Newman, L. F. 2 Warkworth-street, Cambridge.
1889. ‡Newstead, A. H. L., B.A. 38 Green-street, Bethnal Green, N.E.
1912. *Newton, Arthur U. University College, W.C.
1892. ‡Newton, E. T., F.R.S., F.G.S. Florence House, Willow Bridge-road, Canonbury, N.
1908. ‡Nicholls, W. A. 11 Vernham-road, Plumstead, Kent.
1908. ‡Nichols, Albert Russell. 30 Grosvenor-square, Rathmines, Co. Dublin.
1908. §Nicholson, J. W., M.A., D.Sc. Highcliffe, Redcar, Yorkshire.
1887. ‡Nicholson, John Carr, J.P. Moorfield House, Headingley, Leeds.
1884. ‡Nicholson, Joseph S., M.A., D.Sc. (Pres. F, 1893), Professor of Political Economy in the University of Edinburgh.
1911. ‡Nicol, J. C., M.A. The Grammar School, Portsmouth.
1908. ‡Nixon, The Right Hon. Sir Christopher, Bart., M.D., LL.D., D.L. 2 Merrion-square, Dublin.
1863. *Noble, Sir Andrew, Bart., K.C.B., D.Sc., F.R.S., F.R.A.S., F.C.S. (Pres. G, 1890; Council, 1903–06; Local Sec. 1863.) Elswick Works, and Jesmond Dene House, Newcastle-upon-Tyne.
1863. §Norman, Rev. Canon Alfred Merle, M.A., D.C.L., LL.D., F.R.S., F.L.S. The Red House, Berkhamsted.
1888. ‡Norman, George. 12 Brock-street, Bath.

Year of
Election.

1913. §Norman, Sir Henry, M.P. The Corner House, Cowley-street, S.W.
1912. ‡Norrie, Robert. University College, Dundee.
1913. §Norris, F. Edward. Seismograph Station, Hill View, Woodbridge Hill, Guildford.
1894. §Notcutt, S. A., LL.M., B.A., B.Sc. (Local Sec. 1895.) Constitution-hill, Ipswich.
1909. ‡Nugent, F. S. 81 Notre Dame-avenue, Winnipeg, Canada.
1910. §Nunn, T. Percy, M.A., D.Sc. London Day Training College, Southampton-row, W.C.
1913. §Nuttall, T. E., M.D. Middleton, Huncoat, Accrington.
1912. ‡Nuttall, W. H. Cooper Laboratory for Economic Research, Rickmansworth-road, Watford.
1908. ‡Nutting, Sir John, Bart. St. Helen's, Co. Dublin.

1898. *O'Brien, Neville Forth. Fryth, Pyrford, Surrey.
1908. ‡O'Carroll, Joseph, M.D. 43 Merrion-square East, Dublin.
1913. §Ockenden, Maurice A., F.G.S. Oil Well Supply Company, Dashwood House, New Broad-street, E.C.
1883. ‡Odgers, William Blake, M.A., LL.D., K.C. 15 Old-square, Lincoln's Inn, W.C.
1910. *Odling, Marmaduke, B.A., F.G.S. 15 Norham-gardens, Oxford.
1858. *Odling, William, M.B., F.R.S., V.P.C.S. (Pres. B, 1864; Council, 1865–70.) 15 Norham-gardens, Oxford.
1911. *O'Donoghue, Charles H., D.Sc. University College, Gower-street, W.C.
1908. §O'Farrell, Thomas A., J.P. 30 Lansdowne-road, Dublin.
1902. ‡Ogden, James Neal. Claremont, Heaton Chapel, Stockport.
1913. §Ogilvie, A. G. 15 Evelyn-gardens, S.W.
1876. ‡Ogilvie, Campbell P. Lawford-place, Manningtree.
1885. ‡Ogilvie, F. Grant, C.B., M.A., B.Sc., F.R.S.E. (Local Sec. 1892.) Board of Education, S.W.
1912. §Ogilvy, J. W. 18 Bloomsbury-square, W.C.
1905. *Oke, Alfred William, B.A., LL.M., F.G.S., F.L.S. 32 Denmark-villas, Hove, Brighton.
1905. §Okell, Samuel, F.R.A.S. Overley, Langham-road, Bowdon, Cheshire.
1908. §Oldham, Charles Hubert, B.A., B.L., Professor of Commerce in the National University of Ireland. 5 Victoria-terrace, Rathgar, Dublin.
1892. ‡Oldham, H. Yule, M.A., F.R.G.S., Lecturer in Geography in the University of Cambridge. King's College, Cambridge.
1893. *Oldham, R. D., F.R.S., F.G.S. 8 North-street, Horsham, Sussex.
1912. §O'Leary, Rev. William, S.J. Mungret College, Limerick.
1863. ‡Oliver, Daniel, LL.D., F.R.S., F.L.S., Emeritus Professor of Botany in University College, London. 10 Kew Gardens-road, Kew, Surrey.
1887. ‡Oliver, F. W., D.Sc., F.R.S., F.L.S. (Pres. K, 1906), Professor of Botany in University College, London, W.C.
1889. ‡Oliver, Professor Sir Thomas, M.D. 7 Ellison-place, Newcastle-upon-Tyne.
1882. §Olsen, O. T., D.Sc., F.L.S., F.R.A.S., F.R.G.S. 116 St. Andrew's-terrace, Grimsby.
1880. *Ommanney, Rev. E. A. St. Michael's and All Angels, Portsea, Hants.
1908. ‡O'Neill, Rev. G., M.A. University College, St. Stephen's Green, Dublin.
1902. ‡O'Neill, Henry, M.D. 6 College-square East, Belfast.

Year of Election

1913. §Orange, J. A. General Electric Company, Schenectady, New York, U.S.A.
1905. ‡O'Reilly, Patrick Joseph. 7 North Earl-street, Dublin.
1884. *Orpen, Rev. T. H., M.A. Mark Ash, Abinger Common, Dorking.
1901. ‡Orr, Alexander Stewart. 10 Medows-street, Bombay, India.
1909. ‡Orr, John B. Crossacres, Woolton, Liverpool.
1908. *Orr, William. Dungarvan, Co. Waterford.
1904. *Orton, K. J. P., M.A., Ph.D., Professor of Chemistry in University College, Bangor.
1910. *Osborn, T. G. B., M.Sc., Professor of Botany in the University of Adelaide, South Australia.
1901. ‡*Osborne, W. A., D.Sc. University College, W.C.*
1908. ‡O'Shaughnessy, T. L. 64 Fitzwilliam-square, Dublin.
1887. ‡O'Shea, L. T., B.Sc. University College, Sheffield.
1884. ‡Osler, Sir William, Bart., M.D., LL.D., F.R.S., Regius Professor of Medicine in the University of Oxford. 13 Norham-gardens, Oxford.
1881. *Ottewell, Alfred D. 14 Mill Hill-road, Derby.
1906. ‡Owen, Rev. E. C. St. Peter's School, York.
1903. *Owen, Edwin, M.A. Terra Nova School, Birkdale, Lancashire.
1911. §Owens, J. S., M.D., Assoc.M.Inst.C.E. 47 Victoria-street, S.W.
1910. *Oxley, A. E. Rose Hill View, Kimberworth-road, Rotherham.

1909 ‡Pace, F. W. 388 Wellington-crescent, Winnipeg, Canada.
1908. ‡Pack-Beresford, Denis, M.R.I.A. Fenagh House, Bagenalstown, Ireland.
1906. §Page, Carl D. Wyoming House, Aylesbury, Bucks.
1903. *Page, Miss Ellen Iva. Turret House, Felpham, Sussex.
1883. ‡Page, G. W. Bank House, Fakenham.
1913. §Paget, Sir Richard. Old Fallings Hall, Wolverhampton.
1911. §Paget, Stephen, M.A., F.R.C.S. 21 Ladbroke-square, W.
1912. ‡Pahic, Paul. 52 Albert Court, Kensington Gore, S.W.
1911. §Paine, H. Howard. 50 Stow-hill, Newport, Monmouthshire.
1870. *Palgrave, Sir Robert Harry Inglis, F.R.S., F.S.S. (Pres. F, 1883.) Henstead Hall, Wrentham, Suffolk.
1896. ‡Pallis, Alexander. Tatoi, Aigburth-drive, Liverpool.
1878. *Palmer, Joseph Edward. Royal Societies Club, St. James's-street, S.W.
1866. §Palmer, William. Waverley House, Waverley-street, Nottingham.
1880. *Parke, George Henry, F.L.S., F.G.S. Care of W. T. Cooper, Esq., Aysgarth, The Mall, Southgate, N
1904. ‡Parker, E. H., M.A. Thorneycreek, Herschel-road, Cambridge.
1909. §Parker, M. A., B.Sc., F.C.S. (Local Sec. 1909), Professor of Chemistry in the University of Manitoba, Winnipeg, Canada.
1891. ‡Parker, William Newton, Ph.D., F.Z.S., Professor of Biology in University College, Cardiff.
1905. **Parkes, Tom E. P.O. Box* 4580, *Johannesburg.*
1899. *Parkin, John. Blaithwaite, Carlisle.
1905. *Parkin, Thomas. Blaithwaite, Carlisle.
1906. §Parkin, Thomas, M.A., F.L.S., F.Z.S., F.R.G.S. Fairseat, High Wickham, Hastings.
1879. *Parkin, William. The Mount, Sheffield.
1911. ‡Parks, Dr. G. J. 18 Cavendish-road, Southsea.
1913. §Parry, Edward, M.Inst.C.E. Rossmore, Leamington.
1903. §Parry, Joseph, M.Inst.C.E. Woodbury, Waterloo, near Liverpool.
1908. ‡Parry, W. K., M.Inst.C.E. 6 Charlemont-terrace, Kingstown, Dublin.

Year of Election.

1878. ‡PARSONS, Hon. Sir C. A., K.C.B., M.A., Sc.D., F.R.S., M.Inst.C.E. (Pres. G, 1904.) Holeyn Hall, Wylam-on-Tyne.
1904. ‡Parsons, Professor F. G. St. Thomas's Hospital, S.E.
1905. *Parsons, Hon. Geoffrey L. Adderstone House, Jesmond, Newcastle-on-Tyne.
1898. *Partridge, Miss Josephine M. 15 Grosvenor-crescent, S.W.
1887. ‡PATERSON, A. M., M.D., Professor of Anatomy in the University of Liverpool.
1908. ‡Paterson, M., LL.D. 7 Halton-place, Edinburgh.
1909. ‡Paterson, William. Ottawa, Canada.
1897. ‡Paton, D. Noel, M.D. Physiological Laboratory, The University, Glasgow.
1883. *Paton, Rev. Henry, M.A. Airtnoch, 184 Mayfield-road, Edinburgh.
1884. *Paton, Hugh. Box 2400, Montreal, Canada.
1913. §Patrick, Joseph A. North Cliff, King's Heath, Birmingham.
1908. §PATTEN, C. J., M.A., M.D., Sc.D., Professor of Anatomy in the University of Sheffield.
1874. ‡Patterson, W. H., M.R.I.A. 26 High-street, Belfast.
1913. §Patterson, W. Hamilton, M.Sc. The Monksferry Laboratory, Birkenhead.
1913. *Pattin, Harry Cooper, M.A., M.D. King-street House, Norwich.
1913. §Pattison, Mrs. Emma L. Care of Dr. W. Barnard, 3 New-court, Lincoln's Inn, W.C.
1879. *Patzer, F. R. Clayton Lodge, Newcastle, Staffordshire.
1883. ‡Paul, George. 32 Harlow Moor-drive, Harrogate.
1887. *Paxman, James. Standard Iron Works, Colchester.
1912. *Payne, Miss Edith. Care of Mrs. Roberts, Lothair, St. Marychurch, Torquay.
1887. *Payne, Miss Edith Annie. Hatchlands, Cuckfield, Hayward's Heath.
1881. ‡Payne, Mrs. 4 Ulsterville-avenue, Belfast.
1888. *Paynter, J. B. Hendford Manor, Yeovil.
1876. ‡Peace, G. H., M.Inst.C.E. Monton Grange, Eccles, near Manchester.
1906. ‡Peace, Miss Gertrude. 39 Westbourne-road, Sheffield.
1885. ‡PEACH, B. N., LL.D., F.R.S., F.R.S.E., F.G.S. (Pres. C, 1912.) Geological Survey Office, George-square, Edinburgh.
1911. §Peake, Harold J. E. Westbrook House, Newbury.
1913. §Pear, T. H. Dunwood House, Withington, Manchester.
1886. *Pearce, Mrs. Horace. Collingwood, Manby-road, West Malvern.
1883. ‡Pearson, Arthur A., C.M.G. Hillsborough, Heath-road, Petersfield, Hampshire.
1893. *Pearson, Charles E. Hillcrest, Lowdham, Nottinghamshire.
1898. ‡Pearson, George. Bank-chambers, Baldwin-street, Bristol.
1905. §PEARSON, Professor H. H. W., M.A., F.L.S. South African College, Cape Town.
1883. ‡Pearson, Miss Helen E. Oakhurst, Birkdale, Southport.
1906. ‡Pearson, Dr. Joseph. The Museum, Colombo, Ceylon.
1904. ‡Pearson, Karl, M.A., F.R.S., Professor of Eugenics in the University of London. 7 Well-road, Hampstead, N.W.
1909. ‡Pearson, William. Wellington-crescent, Winnipeg, Canada.
Peckitt, Henry. Carlton Husthwaite, Thirsk, Yorkshire.
1855. *PECKOVER, Lord, LL.D., F.S.A., F.L.S., F.R.G.S. Bank House, Wisbech, Cambridgeshire.
1888. ‡Peckover, Miss Alexandrina. Bank House, Wisbech, Cambridgeshire.
1885 ‡Peddie, William, Ph.D., F.R.S.E., Professor of Natural Philosophy in University College, Dundee.

Year of Election.

1884. ‡Peebles, W. E. 9 North Frederick-street, Dublin.
1878. *Peek, William. Villa des Jonquilles, Rue des Roses, Monte Carlo.
1901. *Peel, Right Hon. Viscount. 13 King's Bench-walk, Temple, E.C.
1905. §Peirson, J. Waldie. P.O. Box 561, Johannesburg.
1905. ‡Pemberton, Gustavus M. P.O. Box 93, Johannesburg.
1887. ‡PENDLEBURY, WILLIAM H., M.A., F.C.S. (Local Sec. 1899. Woodford House, Mountfields, Shrewsbury.
1894. ‡Pengelly, Miss. Lamorna, Torquay.
1896. ‡Pennant, P. P. Nantlys, St. Asaph.
1898. ‡Percival, Francis W., M.A., F.R.G.S. 1 Chesham-street, S.W.
1908. ‡Percival, Professor John, M.A. University College, Reading.
1905. ‡Péringuey, L., D.Sc., F.Z.S. South African Museum, Cape Town.
1894. ‡PERKIN, A. G., F.R.S., F.R.S.E., F.C.S., F.I.C. 8 Montpelier-terrace, Hyde Park, Leeds.
1902. *Perkin, F. Mollwo, Ph.D. 199 Piccadilly, W.
1884. ‡PERKIN, WILLIAM HENRY, LL.D. Ph.D., F.R.S., F.R.S.E. (Pres. B. 1900; Council, 1901–07), Waynflete Professor of Chemistry in the University of Oxford. The Museums, Oxford.
1864. *Perkins, V. R. Wotton-under-Edge, Gloucestershire.
1898. *Perman, E. P., D.Sc. University College, Cardiff.
1909. ‡Perry, Rev. Professor E. Guthrie. 246 Kennedy-street, Winnipeg, Canada.
1874. *PERRY, Professor JOHN, M.E., D.Sc., LL.D., F.R.S. (GENERAL TREASURER, 1904– ; Pres. G, 1902; Council, 1901–04.). 14A Campden Hill Court, W.
1913. §Perry, W. J. Care of W. J. Roberts, The Mount, Church Stretton.
1904. *Pertz, Miss D. F. M. 2 Cranmer-road, Cambridge.
1900. *PETAVEL, J. E., M.Sc., F.R.S., Professor of Engineering in the University of Manchester.
1901. ‡Pethybridge, G. H , Ph.D. Royal College of Science, Dublin.
1910. *Petrescu, Captain Dimitrie, R.A., M.Eng. Scoala Superiora de Messern, Bucharest, Rumania.
1895. ‡PETRIE, W. M. FLINDERS, D.C.L., F.R.S. (Pres. H, 1895), Professor of Egyptology in University College, W.C.
1871. *Peyton, John E. H., F.R.A.S., F.G.S. Vale House, St. Helier's, Jersey.
1886. ‡Phelps, Lieut.-General A. 23 Augustus-road, Edgbaston, Birmingham.
1911. ‡Philip, Alexander. Union Bank Buildings, Brechin.
1903. ‡*Philip, James C. 20 Westfield-terrace, Aberdeen.*
1853. *Philips, Rev. Edward. Hollington, Uttoxeter, Staffordshire.
1877. §Philips, T. Wishart. Elizabeth Lodge, Crescent-road, South Woodford, Essex.
1863. ‡Philipson, Sir G. H., D.C.L. 7 Eldon-square, Newcastle-on-Tyne.
1905. ‡Phillimore, Miss C. M. Shiplake House, Henley-on-Thames.
1899. *Phillips, Charles E. S., F.R.S.E. Castle House, Shooter's Hill, Kent.
1910. *Phillips, P. P., Ph.D., Professor of Chemistry in the Thomason Engineering College, Rurki, United Provinces, India.
1890. ‡PHILLIPS, R. W., M.A., D.Sc., F.L.S., Professor of Botany in University College, Bangor. 2 Snowdon-villas, Bangor.
1909. *Phillips, Richard. 15 Dogpole, Shrewsbury.
1883. *Pickard, Joseph William. Oatlands, Lancaster.
1901. §Pickard, Robert H., D.Sc. Billinge View, Blackburn.
1885. *PICKERING, SPENCER P. U., M.A., F.R.S. Harpenden, Herts.
1884. *Pickett, Thomas E., M.D. Maysville, Mason Co., Kentucky, U.S.A

Year of Election.

1907. ‡Pickles, A. R., M.A. Todmorden-road, Burnley.
1888. *Pidgeon, W. R. Lynsted Lodge, St. Edmund's-terrace, Regent's Park, N.W.
1865. ‡PIKE, L. OWEN. 10 Chester-terrace, Regent's Park, N.W.
1896. *Pilkington, A. C. Rocklands, Rainhill, Lancashire.
1905. ‡Pilling, Arnold. Royal Observatory, Cape Town.
1896. *Pilling, William. Rosario, Heene-road, West Worthing.
1905. ‡Pim, Miss Gertrude. Charleville, Blackrock, Co. Dublin.
1911. ‡Pink, H. R. The Mount, Fareham, Hants.
1911. ‡Pink, Mrs. H. R. The Mount, Fareham, Hants.
1911. ‡Pink, Mrs. J. E. The Homestead, Eastern-parade, Southsea.
1908. *Pio, Professor D. A. 14 Leverton-street, Kentish Town, N.W.
1908. ‡Pirrie, The Right Hon. Lord, LL.D., M.Inst.C.E. Downshire House, Belgrave-square, S.W.
1909. ‡Pitblado, Isaac, K.C. 91 Balmoral-place, Winnipeg, Canada.
1893. *PITT, WALTER, M.Inst.C.E. 3 Lansdown-grove, Bath.
1900. *Platts, Walter. Morningside, Scarborough.
1911. *Plimmer, R. H. A. 3 Hall-road, N.W.
1898. ‡Plummer, W. E., M.A., F.R.A.S. The Observatory, Bidston, Birkenhead.
1908. ‡Plunkett, Count G. N. National Museum of Science and Art, Dublin.
1908. ‡Plunkett, Colonel G. T., C.B. Belvedere Lodge, Wimbledon, S.W.
1907. *PLUNKETT, Right Hon. Sir HORACE, K.C.V.O., M.A., F.R.S. Kilteragh, Foxrock, Co. Dublin.
1900. *Pocklington, H. Cabourn, M.A., D.Sc., F.R.S. 11 Regent Park-terrace, Leeds.
1913. §Pocock, R. J. St. Aidan's, 170 Eglinton-road, Woolwich, S.E.
1908. ‡Pollok, James H., D.Sc. 6 St. James's-terrace, Clonshea, Dublin.
1906. *Pontifex, Miss Catherine E. 7 Hurlingham-court, Fulham, S.W.
1891. ‡Pontypridd, Lord. Pen-y-lan, Cardiff.
1911. ‡Poore, Major-General F. H. 1 St. Helen's-parade, Southsea.
1907. §Pope, Alfred, F.S.A. South Court, Dorchester.
1900. *POPE, W. J., M.A., LL.D., F.R.S., Professor of Chemistry in the University of Cambridge.
1892. ‡Popplewell, W. C., M.Sc., Assoc.M.Inst.C.E. Bowden-lane, Marple, Cheshire.
1901. §PORTER, ALFRED W., B.Sc., F.R.S. 87 Parliament Hill-mansions, Lissenden-gardens, N.W.
1905. §PORTER, J. B., D.Sc., M.Inst.C.E., Professor of Mining in the McGill University, Montreal, Canada.
1905. ‡Porter, Mrs. McGill University, Montreal, Canada.
1883. ‡POTTER, M. C., M.A., F.L.S., Professor of Botany in the Armstrong College, Newcastle-upon-Tyne. 13 Highbury, Newcastle-upon-Tyne.
1906. ‡Potter-Kirby, Alderman George. Clifton Lawn, York.
1907. ‡Potts, F. A. University Museum of Zoology, Cambridge.
1908. *Potts, George, Ph.D., M.Sc. Grey University College, Bloemfontein, South Africa.
1886. *POULTON, EDWARD B., M.A., F.R.S., F.L.S., F.G.S., F.Z.S. (Pres. D, 1896; Council, 1895–1901, 1905–12), Professor of Zoology in the University of Oxford. Wykeham House, Banbury-road, Oxford.
1905. ‡Poulton, Mrs. Wykeham House, Banbury-road, Oxford.
1898. *Poulton, Edward Palmer, M.A. Wykeham House, Banbury-road Oxford.

Year of Election.

1913. §Poulton, Miss. Wykeham House, Banbury-road, Oxford.
1894. *Powell, Sir Richard Douglas, Bart., M.D. 62 Wimpole-street, Cavendish-square, W.
1887. §Pownall, George H. 20 Birchin-lane, E.C.
1883. ‡Poynting, J. H., D.Sc., F.R.S. (Pres. A, 1899), Professor of Physics in the University of Birmingham. 10 Ampton-road, Edgbaston, Birmingham.
1913. §Poynting, Mrs. J. H. 10 Ampton-road, Edgbaston, Birmingham.
1908. ‡Praeger, R. Lloyd, B.A., M.R.I.A. Lisnamae, Rathgar, Dublin.
1907. *Prain, Lieut.-Col. Sir David, C.I.E., C.M.G., M.B., F.R.S. (Pres. K, 1909; Council, 1907- .) Royal Gardens, Kew.
1884. *Prankerd, A. A., D.C.L. 66 Banbury-road, Oxford.
1913. *Prankerd, Mrs. Theodora Lisle. 25 Hornsey Lane-gardens, N.
1888. *Preece, W. Llewellyn, M.Inst.C.E. 8 Queen Anne's-gate, S.W.
1904. §Prentice, Mrs. Manning. Thelema, Undercliff-road, Felixstowe.
1892. ‡Prentice, Thomas. Willow Park, Greenock.
1906. ‡Pressly, D. L. Coney-street, York.
1889. ‡Preston, Alfred Eley, M.Inst.C.E., F.G.S. 14 The Exchange, Bradford, Yorkshire.
1903. §Price, Edward E. Oaklands, Oaklands-road, Bromley, Kent.
1888. ‡Price, L. L. F. R., M.A., F.S.S. (Pres. F, 1895; Council, 1898-1904.) Oriel College, Oxford.
1875. *Price, Rees. 163 Bath-street, Glasgow.
1913. §Price, T. Slater. Municipal Technical School, Suffolk-street, Birmingham.
1897. *Price, W. A., M.A. 135 Sandyford-road, Newcastle-on-Tyne.
1908. §Priestley, J. H., B.Sc., Professor of Botany in the University of Leeds.
1909. *Prince, Professor E. E., LL.D., Dominion Commissioner of Fisheries. 206 O'Connor-street, Ottawa, Canada.
1889. *Pritchard, Eric Law, M.D., M.R.C.S. 70 Fairhazel-gardens, South Hampstead, N.W.
1876. *Pritchard, Urban, M.D., F.R.C.S. 26 Wimpole-street, W.
1881. §Procter, John William. Ashcroft, York.
1884. *Proudfoot, Alexander, M.D. Care of E. C. S. Scholefield, Esq., Provincial Librarian, Victoria, B.C., Canada.
1879. *Prouse, Oswald Milton, F.G.S. Alvington, Ilfracombe.
1872. *Pryor, M. Robert. Weston Park, Stevenage, Herts.
1883. *Pullar, Rufus D., F.C.S. Brahan, Perth.
1913. §Pullar, W. B. Coniston, Bridge of Allan, N.B.
1903. ‡Pullen-Burry, Miss. Lyceum Club, 128 Piccadilly, W.
1904. ‡Punnett, R. C., M.A., F.R.S., Professor of Biology in the University of Cambridge. Caius College, Cambridge.
1885. ‡Purdie, Thomas, B.Sc., Ph.D., F.R.S., Emeritus Professor of Chemistry in the University of St. Andrews. 14 South-street, St. Andrews, N.B.
1881. ‡Purey-Cust, Very Rev. Arthur Percival, M.A., Dean of York. The Deanery, York.
1913. §Purser, G. Leslie. Gwynfa, Selly Oak, Birmingham.
1913. §Purser, John, M.Sc. The University, Edgbaston, Birmingham.
1884. *Purves, W. Laidlaw. 20 Stratford-place, Oxford-street, W.
1911. ‡Purvis, J. E. Corpus Christi College, Oxford.
1912. ‡Pycraft, Dr. W. P. British Museum (Natural History), Cromwell-road, S.W.
1898. *Pye, Miss E. St. Mary's Hall, Rochester.
1883. §Pye-Smith, Arnold. 32 Queen Victoria-street, E.C.
1883. ‡Pye-Smith, Mrs. 32 Queen Victoria-street, E.C.

Year of Election

1868. ‡PYE-SMITH, P. H., M.D., F.R.S. 48 Brook-street, W.
1879. ‡Pye-Smith, R. J. 450 Glossop-road, Sheffield.
1911. ‡Pye-Smith, Mrs. R. J. 450 Glossop-road, Sheffield.

1893. ‡Quick, James. 22 Bouverie-road West, Folkestone.
1906. *Quiggin, Mrs. A. Hingston. 88 Hartington-grove, Cambridge.

1879. ‡Radford, R. Heber. 15 St. James's-row, Sheffield.
1912. ‡*Radok, F. 12 Central-hill, Upper Norwood, S.E.*
1911. §Rae, John T. National Temperance League, Paternoster House, Paternoster-row, E.C.
1887. *Ragdale, John Rowland. The Beeches, Stand, near Manchester.
1913. §Railing, Dr. A. H., B.Sc. The General Electric Co., Ltd., Witton, Birmingham.
1893. *Raisin, Miss Catherine A., D.Sc., Bedford College, York-place, Baker-street, W.
1896. *RAMAGE, HUGH, M.A. The Technical Institute, Norwich.
1894. *RAMBAUT, ARTHUR A., M.A., D.Sc., F.R.S., F.R.A.S., M.R.I.A. Radcliffe Observatory, Oxford.
1908. ‡Rambaut, Mrs. Radcliffe Observatory, Oxford.
1912. ‡Ramsay, Colonel R. G. Wardlaw. Whitehill, Rosewell, Midlothian.
1876. *RAMSAY, Sir WILLIAM, K.C.B., Ph.D., D.Sc., F.R.S. (PRESIDENT, 1911; Pres. B, 1897; Council 1891–98). 19 Chester-terrace, Regent's Park, N.W.
1883. ‡Ramsay, Lady. 19 Chester-terrace, Regent's Park, N.W.
1913. §Ramsden, William. Blacker-road, Huddersfield.
1869. **Rance, H. W. Henniker, LL.D. 10 Castletown-road, W.*
1907. ‡Rankine, A. O. 18 Loveday-road, Ealing, W.
1868. *Ransom, Edwin, F.R.G.S. 24 Ashburnham-road, Bedford.
1861. ‡RANSOME, ARTHUR, M.A., M.D., F.R.S. (Local Sec. 1861.) Sunnyhurst, Dean Park, Bournemouth.
1903. ‡Rastall, R. H. Christ's College, Cambridge.
1914. §Rathbone, Herbert R. 15 Lord-street, Liverpool.
1892. *Rathbone, Miss May. Backwood, Neston, Cheshire.
1913. §Raw, Frank, B.Sc., F.G.S. The University, Edmund-street, Birmingham.
1908. *Raworth, Alexander. St. John's Manor, Jersey.
1905. ‡Rawson, Colonel Herbert E., C.B., R.E., F.R.G.S. Home Close, Heronsgate, Herts.
1868. *RAYLEIGH, The Right Hon. Lord, O.M., M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.G.S. (PRESIDENT, 1884; TRUSTEE, 1883– ; Pres. A, 1882; Council, 1878–83), Professor of Natural Philosophy in the Royal Institution, London. Terling Place, Witham, Essex.
1883. *Rayne, Charles A., M.D., M.R.C.S. St. Mary's Gate, Lancaster.
1912. §Rayner, Miss M. C. University College, Reading.
1897. *Rayner, Edwin Hartree, M.A. 40 Gloucester-road, Teddington, Middlesex.
1907. ‡Rea, Carleton, B.C.L. 34 Foregate-street, Worcester.
1913. §Read, Carveth, M.A. 73 Kensington Gardens-square, W.
1896. *READ, Sir CHARLES H., LL.D., F.S.A. (Pres. H, 1899.) British Museum, W.C.
1913. §Reade, Charles C. 3 Gray's Inn-place, Gray's Inn, W.C.

Year of Election.

1902. ‡Reade, R. H. Wilmount, Dunmurry.
1884. §Readman, J. B., D.Sc., F.R.S.E. Belmont, Hereford.
1890. *Redwood, Sir Boverton, Bart., D.Sc., F.R.S.E., F.C.S. The Cloisters, 18 Avenue-road, Regent's Park, N.W.
1908. ‡Reed, Sir Andrew, K.C.B., C.V.O., LL.D. 23 Fitzwilliam-square, Dublin.
1905. §Reed, J. Howard, F.R.G.S. 16 St. Mary's Parsonage, Manchester.
1891. *Reed, Thomas A. Bute Docks, Cardiff.
1894. *Rees, Edmund S. G. Dunscar, Oaken, near Wolverhampton.
1903. §Reeves, E. A., F.R.G.S. Hillside, Reigate-road, Reigate.
1911. §REEVES, Hon. W. PEMBER. (Pres. F. 1911.) London School of Economics, Clare Market, W.C.
1906. *Reichel, Sir H. R., LL.D., Principal of University College, Bangor. Penrallt, Bangor, North Wales.
1910. **Reid, Alfred, M.B., M.R.C.S. Taiping, Perak, F.M.S.*
1901. *Reid, Andrew T. 10 Woodside-terrace, Glasgow.
1904. ‡Reid, Arthur H. 30 Welbeck-street, W.
1881. §Reid, Arthur S., M.A., F.G.S. Trinity College, Glenalmond, N.B.
1883. *REID, CLEMENT, F.R.S., F.L.S., F.G.S. One Acre, Milford-on-Sea, Hants.
1903. *Reid, Mrs. E. M., B.Sc. One Acre, Milford-on-Sea, Hants.
1892. ‡REID, E. WAYMOUTH, B.A., M.B., F.R.S., Professor of Physiology in University College, Dundee.
1908. ‡REID, GEORGE ARCHDALL, M.B., C.M., F.R.S.E. 9 Victoria-road South, Southsea.
1901. *Reid, Hugh. Belmont, Springburn, Glasgow.
1901. ‡Reid, John. 7 Park-terrace, Glasgow.
1909. ‡Reid, John Young. 329 Wellington-crescent, Winnipeg, Canada.
1904. ‡Reid, P. J. Marton Moor End, Nunthorpe, R.S.O., Yorkshire.
1912. §Reid, Professor R. W. M.D. 37 Albyn-place, Aberdeen.
1897. ‡Reid, T. Whitehead, M.D. St. George's House, Canterbury.
1892. ‡Reid, Thomas. Municipal Technical School, Birmingham.
1887. *Reid, Walter Francis. Fieldside, Addlestone, Surrey.
1912. §Reinheimer, Hermann. 43 King Charles-road, Surbiton.
1875. ‡REINOLD, A. W., C.B., M.A., F.R.S. (Council, 1890-95). 9 Vanbrugh Park-road, Blackheath, S.E.
1894. ‡Rendall, Rev. G. H., M.A., Litt.D. Charterhouse, Godalming.
1891. *Rendell, Rev. James Robson, B.A. Whinside, Whalley-road, Accrington.
1903. *RENDLE, Dr. A. B., M.A., F.R.S., F.L.S. 28 Holmbush-road, Putney, S.W.
1889. *Rennie, George B. 20 Lowndes-street, S.W.
1906. ‡Rennie, John, D.Sc. Natural History Department, University of Aberdeen.
1905. *Renton, James Hall. Rowfold Grange, Billingshurst, Sussex.
1912. ‡Rettie, Theodore. 10 Doune-terrace, Edinburgh.
1904. ‡REUNERT, THEODORE, M.Inst.C.E. P.O. Box 92, Johannesburg
1912. ‡Rew, R. H., C.B. Board of Agriculture and Fisheries, 3 St. James's-square, S.W.
1905. §Reyersbach, Louis. Care of Messrs. Wernher, Beit, & Co., 1 London Wall-buildings, E.C.
1883. *Reynolds, A. H. 271 Lord-street, Southport.
1913. §Reynolds, J. H. Low Wood, Harborne, Birmingham.
1871. ‡REYNOLDS, JAMES EMERSON, M.D., D.Sc., F.R.S., F.C.S., M.R.I.A. (Pres. B. 1893; Council, 1893-99.) 3 Inverness-gardens, W.
1900. *Reynolds, Miss K. M. 8 Darnley-road, Notting Hill, W.

Year of Election

1906. ‡Reynolds, S. H., M.A., Professor of Geology and Zoology in the University of Bristol.
1907. §Reynolds, W. Birstall Holt, near Leicester.
1899. *Rhys, The Right Hon. Professor Sir John, D.Sc. (Pres. H, 1900.) Jesus College, Oxford.
1877. *Riccardi, Dr. Paul, Secretary of the Society of Naturalists. Riva Muro 14, Modena, Italy.
1905. §Rich, Miss Florence, M.A. Granville School, Granville-road, Leicester.
1906. ‡Richards, Rev. A. W. 12 Bootham-terrace, York.
1869. *Richardson, Charles. 3 Cholmley-villas, Long Ditton, Surrey.
1912. ‡Richardson, Harry, M.Inst.E.E. Electricity Supply Department, Dudhope Crescent-road, Dundee.
1889. ‡Richardson, Hugh, M.A. 18 Bootham-crescent, York.
1884. *Richardson, J. Clarke Derwen Fawr, Swansea.
1896. *Richardson, Nelson Moore, B.A , F.E.S. Montevideo, Chickerell, near Weymouth.
1901. *Richardson, Owen Willans, M.A., D.Sc., F.R.S., Wheatstone Professor of Physics in King's College, London, W.C.
1883. *Rideal, Samuel, D.Sc., F.C S. 28 Victoria-street, S.W
1911. §Ridgeway, Miss A. R. 83 The Broadway, Watford.
1902. §Ridgeway, William, M.A., D.Litt., F.B.A. (Pres. H, 1908), Professor of Archæology in the University of Cambridge. Flendyshe, Fen Ditton, Cambridge.
1913. §Ridler, Miss C. C. Coniston, Hunsdon-road, Torquay.
1894. ‡Ridley, E. P., F.G.S. (Local Sec. 1895.) Burwood, Westerfield-road, Ipswich.
1881. *Rigg, Arthur. 150 Blomfield-terrace, W.
1883. *Rigg, Edward, C B., I.S.O., M.A. Royal Mint, E.
1892. ‡Rintoul, D., M.A. Clifton College, Bristol.
1912. §Rintoul, Miss L. J. Lahill, Largo, Fife.
1910. ‡Ripper, William, Professor of Engineering in the University of Sheffield.
1903. *Rivers, W. H. R., M.D., F.R.S. (Pres. H, 1911.) St. John's College, Cambridge.
1913. §Rivett, A. C. D., B A , Ph.D (General Organising Secretary, 1914) The University of Melbourne, Victoria.
1908. *Roaf, Herbert E., M.D., D.Sc. 44 Rotherwick-road, Hendon, N.W.
1898. *Robb, Alfred A., M.A., Ph.D. Lisnabreeny House, Belfast.
1914. §Robb, James Jenkins, M.D. Harlow, 19 Linden-road, Bournville, Birmingham.
1902. *Roberts, Bruno. 30 St. George's-square, Regent's Park, N.W.
1887. *Roberts, Evan. 27 Crescent-grove, Clapham Common, S.W.
1896. ‡Roberts, Thomas J. Ingleside, Park-road, Huyton, near Liverpool.
1913. §Robertson, Andrew. Engineering Laboratories, Victoria University, Manchester.
1897. §Robertson, Sir George S., K.C.S.I., M.P. (Pres. E, 1900.) 2 Mitre Court-buildings, Temple, E.C.
1897. ‡Robertson, Professor J. W., C.M.G., LL.D. The Macdonald College, St. Anne de Bellevue, Quebec, Canada.
1912. §Robertson, R. A., M.A., B.Sc., F.R.S.E., Lecturer on Botany in the University of St. Andrews.
1901. *Robertson, Robert, B.Sc., M.Inst.C.E. Carnbooth, Carmunnock, Lanarkshire.
1913. *Robins, Edward, M.Inst.C E., F.R.G.S. Lobito, Angola, Portuguese South-West Africa.

Year of Election.

1913. §Robinson, A. H., M.D. St. Mary's Infirmary, Highgate Hill, N.
1886. *Robinson, Charles Reece. 176 Gerrard-street, Aston, Birmingham.
1909. ‡Robinson, E. M. 381 Main-street, Winnipeg, Canada.
1910. §Robinson, Lady E. Maude. The Manor, Worksop.
1903. ‡Robinson, G. H. 1 Weld-road, Southport.
1902. ‡Robinson, Herbert C. Holmfield, Aigburth, Liverpool.
1911. ‡Robinson, J. J. 'West Sussex Gazette' Office, Arundel.
1902. ‡Robinson, James, M.A., F.R.G.S. Dulwich College, Dulwich, S.E.
1912. §Robinson, James. North-terrace, Seghill, Northumberland.
1888. ‡Robinson, John, M.Inst.C.E. 8 Vicarage-terrace, Kendal.
1908. *Robinson, John Gorges, B.A. Cragdale, Settle, Yorkshire.
1910. ‡Robinson, John Hargreaves. Cable Ship 'Norseman,' Western Telegraph Co., Caixa no Correu No. 117, Pernambuco, Brazil.
1895. *Robinson, Joseph Johnson. 8 Trafalgar-road, Birkdale, Southport.
1899. *Robinson, Mark, M.Inst.C.E. Parliament-chambers, Westminster, S.W.
1875. *Robinson, Robert, M.Inst.C.E. Beechwood, Darlington.
1908. ‡Robinson, Robert. Field House, Chesterfield.
1904. ‡Robinson, Theodore R. 25 Campden Hill-gardens, W.
1909. ‡Robinson, Captain W. 264 Roslyn-road, Winnipeg, Canada.
1909. ‡Robinson, Mrs. W. 264 Roslyn-road, Winnipeg, Canada.
1904. ‡Robinson, W. H. Kendrick House, Victoria-road, Penarth.
1870. *Robson, E. R. Palace Chambers, 9 Bridge-street, Westminster, S.W.
1912. ‡Robson, W. G. 50 Farrington-street, Dundee.
1872. *Robson, William. 12 Albert-terrace, Edinburgh.
1896. ‡Rodger, A. M. Natural History Museum, Perth.
1885. *Rodger, Edward. 1 Clairmont-gardens, Glasgow.
1905. ‡Roebuck, William Denison, F.L.S. 259 Hyde Park-road, Leeds
1908. §Rogers, A. G. L. Board of Agriculture and Fisheries, 8 Whitehall-place, S.W.
1898 ‡Rogers, Bertram, M.D. (Local Sec. 1898.) 11 York-place, Clifton, Bristol.
1913. §Rogers, F., D.Eng., B.A., M.Sc. Rowardennan, Chelsea-road, Sheffield.
1913. §Rogers, Sir Hallewell, Greville Lodge, Sir Harry's-road, Edgbaston, Birmingham.
1907. ‡Rogers, John D. 85 St. George's-square, S.W.
1890. *Rogers, L. J., M.A., Professor of Mathematics in the University of Leeds. 15 Regent Park-avenue, Leeds.
1906. ‡Rogers, Reginald A. P. Trinity College, Dublin.
1909. ‡Rogers, Hon. Robert. Roslyn-road, Winnipeg, Canada.
1884. *Rogers, Walter. Lamorva, Falmouth.
1876. ‡Rollit, Sir A. K., LL.D., D.C.L., Litt. D. St. Anne's Hall, near Chertsey-on-Thames, Surrey.
1855. *Roscoe, The Right Hon. Sir Henry Enfield, B.A., Ph.D., LL.D., D.C.L., F.R.S. (President, 1887; Pres. B, 1870, 1884; Council, 1874-81; Local Sec. 1861.) 10 Bramham-gardens, S.W.
1905. ‡Rose, Miss G. Mabel. Ashley Lodge, Oxford.
1883. *Rose, J. Holland, Litt.D. Walsingham, Millington-road, Cambridge.
1894. *Rose, T. K., D.Sc., Chemist and Assayer to the Royal Mint. 6 Royal Mint, E.
1905. *Rosedale, Rev. H. G., D.D., F.S.A. 7 Gloucester-street, S.W.
1905. *Rosedale, Rev. W. E., D.D. St. Mary Bolton's Vicarage, South Kensington, S.W.

Year of Election.

1900. ‡ROSENHAIN, WALTER, B.A., F.R.S. Warrawee, Coombe-lane, Kingston Hill, Surrey.
1909. ‡Ross, D. A. 116 Wellington-crescent, Winnipeg, Canada.
1859. *Ross, Rev. James Coulman. Wadworth Hall, Doncaster.
1908. ‡Ross, Sir John, of Bladensburg, K.C.B. Rostrevor House, Rostrevor, Co. Down.
1912. ‡Ross, Miss Joan M. Hazelwood, Warlingham, Surrey.
1902. ‡Ross, John Callender. 46 Holland-street, Campden-hill, W.
1901. ‡Ross, Colonel Sir RONALD, K.C.B., F.R.S., Professor of Tropical Sanitation in the University of Liverpool. The University, Liverpool.
1891. *Roth, H. Ling. Briarfield, Shibden, Halifax, Yorkshire.
1911. *Rothschild, Hon. L. Walter, M.P., D.Sc., Ph.D., F.R.S. Tring Park, Tring.
1901. *Rottenburg, Paul, LL.D. Care of Messrs. Leister, Bock, & Co., Glasgow.
1899. *Round, J. C., M.R.C.S. 19 Crescent-road, Sydenham Hill, S.E.
1909. ‡Rounthwaite, C. H. E. Engineer's Office, Grand Trunk Pacific Railway of Canada, Winnipeg.
1884. *Rouse, M. L., B.A. 47 Berlin-road, Catford, S.E.
1905. §Rousselet, Charles F. Fit Island, Bittacy Hill, Mill Hill, N.W.
1901. ‡Rowallan, the Right Hon. Lord. Thornliebank House, Glasgow.
1903. *Rowe, Arthur W., M.B., F.G.S. Shottendane, Margate.
1890. ‡Rowley, Walter, M.Inst.C.E., F.S.A. Alderhill, Meanwood, Leeds.
1881. *Rowntree, Joseph. 38 St. Mary's, York.
1910. §Rowse, Arthur A., B.A., B.Sc. Engineering Laboratory, Cambridge.
1875. *RÜCKER, Sir ARTHUR W., M.A., D.Sc., LL.D., F.R.S. (PRESIDENT, 1901; TRUSTEE, 1898- ; GENERAL TREASURER, 1891-98; Pres. A, 1894; Council, 1888-91.) Everington House, Newbury, Berkshire.
1869. §RUDLER, F. W., I.S.O., F.G.S. Ethel Villa, Tatsfield, Westerham.
1901. *Rudorf, C. C. G., Ph.D., B.Sc. Ivor, Cranley-gardens, Muswell Hill, N.
1905. *Ruffer, Marc Armand, C.M.G., M.A., M.D., B.Sc. Quarantine International Board, Alexandria.
1905. ‡Ruffer, Mrs. Alexandria.
1904. ‡Ruhemann, Dr. S. 3 Selwyn-gardens, Cambridge.
1909. ‡Rumball, Rev. M. C., B.A. Morden, Manitoba, Canada.
1896. *Rundell, T. W., F.R.Met.Soc. 3 Fenwick-street, Liverpool.
1911. ‡Rundle, Henry, F.R.C.S. 13 Clarence-parade, Southsea.
1912. *Rusk, Robert R., M.A., Ph.D. 4 Barns-crescent, Ayr.
1904. ‡Russell, E. J., D.Sc. Rothamsted Experimental Station, Harpenden, Herts.
1875. *Russell, The Hon. F. A. R. Steep, Petersfield.
Russell, John. 39 Mountjoy-square, Dublin.
1883. *Russell, J. W. 28 Staverton-road, Oxford.
1852. *Russell, Norman Scott. Arts Club, Dover-street, W.
1908. ‡Russell, Robert. Arduagremia, Haddon-road, Dublin.
1908. ‡RUSSELL, Right Hon T. W., M.P. Olney, Terenure, Co. Dublin.
1886. ‡Rust, Arthur. Eversleigh, Leicester.
1909. *Rutherford, Hon. Alexander Cameron. Strathcona, Alberta, Canada.
1907. §RUTHERFORD, SIR ERNEST, M.A., D.Sc., F.R.S. (Pres. A, 1909), Professor of Physics in the University of Manchester.
1909. ‡Ruttan, Colonel H. N. Armstrong's Point, Winnipeg, Canada.
1908. ‡Ryan, Hugh, D.Sc. Omdurman, Orwell Park, Rathgar, Dublin.
1905. ‡Ryan, Pierce. Rosebank House, Rosebank, Cape Town.

Year of Election.

1909. ‡Ryan, Thomas. Assiniboine-avenue, Winnipeg, Canada.
1906. *RYMER, Sir JOSEPH SYKES. The Mount, York.

1903. ‡SADLER, M. E., C.B., LL.D. (Pres. L. 1906), Vice-Chancellor of the University of Leeds. 41 Headingley-lane, Leeds.
1883. ‡Sadler, Robert. 7 Lulworth-road, Birkdale, Southport.
1871. ‡Sadler, Samuel Champernowne. Church House, Westminster, S.W.
1903. ‡Sagar, J. The Poplars, Savile Park, Halifax.
1873. *Salomons, Sir David, Bart., F.G.S. Broomhill, Tunbridge Wells.
1904. †SALTER, A. E., D.Sc., F.G.S. 5 Clifton-place, Brighton.
1911. §Sampson, R. A., M.A., F.R.S., Astronomer Royal for Scotland. Royal Observatory, Edinburgh.
1901. ‡Samuel, John S., J.P., F.R.S.E. City Chambers, Glasgow.
1907. *Sand, Dr. Henry J. S. University College, Nottingham.
Sandes, Thomas, A.B. Sallow Glin, Tarbert, Co. Kerry.
1896. §Saner, John Arthur, M.Inst.C.E. Toolerstone, Sandiway, Cheshire.
1896. ‡Saner, Mrs. Toolerstone, Sandiway, Cheshire.
1903. ‡Sankey, Captain H. R., R.E., M.Inst.C.E. Palace-chambers, 9 Bridge-street, S.W.
1886. ‡Sankey, Percy E. 44 Russell-square, W.C.
1905. ‡*Sargant, E. B. Quarry Hill, Reigate.*
1896. *SARGANT, Miss ETHEL, F.L.S. (Pres. K, 1913.) The Old Rectory, Girton, Cambs.
1907. ‡Sargent, H. C. Ambergate, near Derby.
1813. §Saundby, Robert, M.D. Great Charles-street, Birmingham.
1903. *SAUNDERS, Miss E. R. Newnham College, Cambridge.
1901. ‡*Sawers, W. D. 1 Athole Gardens-place, Glasgow.*
1887. §SAYCE, Rev. A. H., M.A., D.D. (Pres. H, 1887), Professor of Assyriology in the University of Oxford. Queen's College, Oxford.
1906. ‡Sayer, Dr. Ettie. 35 Upper Brook-street, W.
1883. *Scarborough, George. Whinney Field, Halifax, Yorkshire.
1903. §SCARISBRICK, Sir CHARLES, J.P. Scarisbrick Lodge, Southport.
1903. ‡Scarisbrick, Lady. Scarisbrick Lodge, Southport.
1879. *SCHAFER, Sir E. A., LL.D., D.Sc., M.D., F.R.S. (PRESIDENT, 1912; GENERAL SECRETARY, 1895–1900; Pres. I, 1894; Council, 1887–93), Professor of Physiology in the University of Edinburgh.
1888. *SCHARFF, ROBERT F., Ph.D., B.Sc., Keeper of the Natural History Department, National Museum, Dublin. Knockranny, Bray, Co. Wicklow.
1914. §Scharff, Mrs. Knockranny, Bray, Co. Wicklow.
1914. §Scharff, J. W. Knockranny, Bray, Co. Wicklow.
1880. *Schemmann, Louis Carl. Neueberg 12, Hamburg.
1905. ‡SCHONLAND, S., Ph.D. Albany Museum, Grahamstown, Cape Colony.
1908. §Schrödter, Dr. E. 27 Breite-strasse, Düsseldorf, Germany.
1873. *SCHUSTER, ARTHUR, Ph.D., Sec. R.S., F.R.A.S. (Pres. A, 1892; Council, 1887–93.) Yeldall, Twyford, Berks.
1883. *SCLATER, W. LUTLEY, M.A., F.Z.S. Odiham Priory, Winchfield.
1905. ‡Sclater, Mrs. W. L. Odiham Priory, Winchfield.
1913. §Scoble, Walter A., B.Sc., A.M.Inst.C.E. City and Guilds Technical College, Leonard-street, E.C.
1881. *SCOTT, ALEXANDER, M.A., D.Sc., F.R.S., F.C.S. 34 Upper Hamilton-terrace, N.W.
1878. *Scott, Arthur William, M.A., Professor of Mathematics and Natural Science in St. David's College, Lampeter.

Year of Election.

1889. *SCOTT, D. H., M.A., Ph.D., F.R.S., Pres.L.S. (GENERAL SECRETARY, 1900–03; Pres. K, 1896.) East Oakley House, Oakley, Hants; and Athenæum Club, Pall Mall, S.W.
1857. *SCOTT, ROBERT H., M.A., D.Sc., F.R.S., F.R.Met.S. 6 Elm Park-gardens, S.W.
1902. ‡Scott, William R., M.A., Litt D. St. Regulus, St. Andrews, Scotland.
1895. ‡Scott-Elliot, Professor G. F., M.A., B.Sc., F.L.S. Newton, Dumfries.
1883. ‡Scrivener, Mrs. Haglis House, Wendover.
1909. ‡*Scudamore, Colonel F. W. Chelsworth Hall, Suffolk.*
1895. ‡Scull, Miss E. M. L. St. Edmund's, 10 Worsley-road, Hampstead, N.W.
1890. *Searle, G. F. C., Sc.D., F.R.S. Wyncote, Hills-road, Cambridge.
1906. *See, T. J. J., A.M., Ph.D., F.R.A.S., Professor of Mathematics, U.S. Navy. Naval Observatory, Mare Island, California.
1907. §Seligmann, Dr. C. G. 36 Finchley-road, N.W.
1911. *Seligmann, Mrs. C. G. 36 Finchley-road, N.W.
1913. §Seligmann, Miss Emma A. 61 Kirklee-road, Kelvinside, Glasgow.
1904. ‡Sell, W. J. 19 Lensfield-road, Cambridge.
1909. ‡Sellars, H. Lee. 225 Fifth-avenue, New York, U.S.A.
1888. *SENIER, ALFRED, M.D., Ph.D., F.C.S. (Pres. B, 1912), Professor of Chemistry in University College, Galway.
1888. *SENNETT, ALFRED R., A.M.Inst.C.E. Duffield, near Derby.
1870. *Sephton, Rev. J. 90 Huskisson-street, Liverpool.
1910. ‡Seton, R. S., B.Sc. The University, Leeds.
1895. *Seton-Karr, H. W. 8 St. Paul's-mansions, Hammersmith, W.
1892. *SEWARD, A. C., M.A., D.Sc., F.R.S., F.G.S. (Pres. K, 1903; Council, 1901–07; Local Sec. 1904), Professor of Botany in the University of Cambridge. Westfield, Huntingdon-road, Cambridge.
1913. §Seward, Mrs. Westfield, Huntingdon-road, Cambridge.
1899. §Seymour, Henry J., B.A., F.G.S., Professor of Geology in the National University of Ireland. Earlsfort-terrace, Dublin.
1891. ‡Shackell, E. W. 191 Newport-road, Cardiff.
1905. *Shackleford, W. C. Burnt Green, Worcestershire.
1904. ‡Shackleton, Lieutenant Sir Ernest H., M.V.O., F.R.G.S. 9 Regent-street, S.W.
1902. ‡SHAFTESBURY, The Right Hon. the Earl of, K.P., K.C.V.O. Belfast Castle, Belfast.
1913. §Shakespear, G.A., D.Sc., M.A. 21 Woodland-road, Northfield, Worcestershire.
1901. *Shakespear, Mrs. G. A. 21 Woodland-road, Northfield, Worcestershire.
1906. ‡Shann, Frederick. 6 St. Leonard's, York.
1878. ‡SHARP, DAVID, M.A., M.B., F.R.S., F.L.S. Lawnside, Brockenhurst, Hants.
1904. ‡Sharples, George. 181 Great Cheetham-street West, Higher Broughton, Manchester.
1910. §Shaw, J. J. Sunnyside, Birmingham-road, West Bromwich.
1889. *Shaw, Mrs. M. S., B.Sc. Brookhayes, Exmouth.
1883. *SHAW, W. N., M.A., Sc.D., F.R.S. (Pres. A, 1908; Council, 1895–1900, 1904–07.) Meteorological Office, Exhibition-road, South Kensington, S.W.
1883. ‡Shaw, Mrs. W. N. 10 Moreton-gardens, South Kensington, S.W.
1904. ‡*Shaw-Phillips, Miss. 70 Westbourne-terrace, Hyde Park, W.*
1903. ‡Shaw-Phillips, T., J.P. The Times Library Club, 380 Oxford-street, W.

Year of
Election.

1912. ‡Shearer, C. Clare College, Cambridge.
1905. ‡Shenstone, Miss A. Sutton Hall, Barcombe, Lewes.
1905. ‡Shenstone, Mrs. A. E. G. Sutton Hall, Barcombe, Lewes.
1865. ‡Shenstone, Frederick S. Sutton Hall, Barcombe, Lewes.
1900. §SHEPPARD, THOMAS, F.G.S. The Municipal Museum, Hull.
1908. §Sheppard, W. F., Sc.D., LL.M. Board of Education, Whitehall, S.W.
1883. ‡Sherlock, David. Rahan Lodge, Tullamore, Dublin.
1883. ‡Sherlock, Mrs. David. Rahan Lodge, Tullamore, Dublin.
1896. ‡SHERRINGTON, C. S., M.D., D.Sc., F.R.S. (Pres. I, 1904; Council, 1907–), Professor of Physiology in the University of Oxford.
1888. *Shickle, Rev. C. W., M.A., F.S.A. St. John's Hospital, Bath.
1908. *Shickle, Miss Mabel G. M. 9 Cavendish-crescent, Bath.
1902. *Shillington, T. Foulkes, J.P. Dromart, Antrim-road, Belfast.
1883. *Shillitoe, Buxton, F.R.C.S. Ardvernis, 3 Richmond-gardens, Bournemouth.
1887. *SHIPLEY, ARTHUR E., M.A., D.Sc., F.R.S. (Pres. D, 1909; Council, 1904-11), Master of Christ's College, Cambridge.
1897. ‡SHORE, Dr. LEWIS E. St. John's College, Cambridge.
1882. ‡SHORE, T. W., M.D., B.Sc., Lecturer on Comparative Anatomy at St. Bartholomew's Hospital. 6 Kingswood-road, Upper Norwood, S.E.
1901. ‡Short, Peter M., B.Sc. 1 Deronda-road, Herne Hill, S.E.
1908. §Shorter, Lewis R., B.Sc. 29 Albion-street, W.
1904. *Shrubsall, F. C., M.A., M.D. 34 Lime-grove, Uxbridge-road, W.
1910. ‡Shuttleworth, T. E. 5 Park-avenue, Riverdale-road, Sheffield.
1889. ‡Sibley, Walter K., M.A., M.D. 6 Cavendish-place, W.
1902. ‡Siddons, A. W., M.A. Harrow-on-the-Hill, Middlesex.
1883. *Sidebotham, Edward John. Erlesdene, Bowdon, Cheshire.
1877. *Sidebotham, Joseph Watson. Merlewood, Bowdon, Cheshire.
1913. *Sidgwick, N. V. Lincoln College, Oxford.
1873. *SIEMENS, ALEXANDER, M.Inst.C.E. Caxton House, Westminster, S.W.
1905. ‡Siemens, Mrs. A. Caxton House, Westminster, S.W.
1903. *Silberrad, Dr. Oswald. Buckhurst Hill, Essex.
1871. *SIMPSON, Sir ALEXANDER R., M.D., Emeritus Professor of Midwifery in the University of Edinburgh. 52 Queen-street, Edinburgh.
1913. *Simpson, J. A., M.A., D.Sc. 62 Academy-street, Elgin.
1863. ‡Simpson, J. B., F.G.S. Hedgefield House, Blaydon-on-Tyne.
1909. ‡Simpson, Professor J. C. McGill University, Montreal, Canada.
1908. ‡Simpson, J. J., M.A., B.Sc. Zoological Department, Marischal College, Aberdeen.
1901. *Simpson, Professor J. Y., M.A., D.Sc., F.R.S.E. 25 Chester-street, Edinburgh.
1907. ‡Simpson, Lieut.-Colonel R. J. S., C.M.G. 66 Shooters Hill-road, Blackheath, S.E.
1909. *Simpson, Samuel, B.Sc. Entebbe, Uganda.
1909. ‡Simpson, Sutherland, M.D. Cornell University Medical College, Ithaca, New York, U.S.A.
1896. *SIMPSON, W., F.G.S. Catteral Hall, Settle, Yorkshire.
1884. *Simpson, Professor W. J. R., C.M.G., M.D. 31 York-terrace, Regent's Park, N.W.
1909. ‡Sinclair, J. D. 77 Spence-street, Winnipeg.
1912. §Sinclair, Sir John R. G., Bart., D.S.O. Barrock House, Wick, N.B.
1874. ‡SINCLAIR, Right Hon. THOMAS. (Local Sec. 1874.) Dunedin, Belfast.

Year of Election.

1907. *Sircar, Dr. Amrita Lal, L.M.S., F.C.S. 51 Sankaritola, Calcutta.
1905. *SJÖGREN, Professor H. Natural History Museum, Stockholm, Sweden.
1902. ‡Skeffington, J. B., M.A., LL.D. Waterford.
1906. ‡Skerry, H. A. St. Paul's-square, York.
1883. ‡Skillicorne, W. N. 9 Queen's-parade, Cheltenham.
1910. ‡Skinner, J. C. 76 Ivy Park-road, Sheffield.
1898. ‡SKINNER, SIDNEY, M.A. (Local Sec. 1904.) South-Western Polytechnic, Manresa-road, Chelsea, S.W.
1905. *Skyrme, C. G. Baltimore, 6 Grange-road, Upper Norwood, S.E.
1913. §Skyrme, Mrs. C. G. Baltimore, 6 Grange-road, Upper Norwood, S.E.
1913. *SLADE, R. E., D.Sc. Muspratt Laboratory, The University, Liverpool.
1887. ‡Small, Evan W., M.A., B.Sc., F.G.S. 48 Kedleston-road, Derby.
1903. *Smallman, Raleigh S. Eliot Lodge, Albemarle-road, Beckenham.
1889. *SMART, Professor WILLIAM, LL.D. (Pres. F, 1904.) Nunholme, Dowanhill, Glasgow.
1902. ‡Smedley, Miss Ida. 36 Russell-square, W.C.
1911. ‡Smiles, Samuel. The Quarry, Sanderstead-road, Sanderstead, Surrey.
1911. §Smith, A. Malins, M.A. St. Audrey's Mill House, Thetford, Norfolk
1892. ‡Smith, Alexander, B.Sc., Ph.D., F.R.S.E. Department of Chemistry, Columbia University, New York, U.S.A.
1908 ‡Smith, Alfred. 30 Merrion-square, Dublin.
1897. ‡Smith, Andrew, Principal of the Veterinary College, Toronto, Canada.
1901. *SMITH, Miss ANNIE LORRAIN. 20 Talgarth-road, West Kensington, W.
1873. ‡Smith, C. Sidney-Sussex College, Cambridge.
1889. *Smith, Professor C. Michie, C.I.E., B.Sc., F.R.S.E., F.R.A.S. The Observatory, Kodaikanal, South India.
1910. ‡Smith, Charles. 11 Winter-street, Sheffield.
1900. §Smith, E. J. Grange House, Westgate Hill, Bradford.
1913. *Smith, Miss E. M. 40 Owlstone-road, Newnham, Cambridge.
1908. ‡Smith, E. Shrapnell. 7 Rosebery-avenue, E.C.
1886. *Smith, Mrs. Emma. Hencotes House, Hexham.
1901. §Smith, F. B. Care of A. Croxton Smith, Esq., Burlington House, Wandle-road, Upper Tooting, S.W.
1866. *Smith, F. C. Bank, Nottingham.
1911. §Smith, F. E. National Physical Laboratory, Teddington, Middlesex.
1912. §Smith, Rev. Frederick. The Parsonage, South Queensferry.
1897. ‡SMITH, G. ELLIOT, M.D., F.R.S. (Pres. H, 1912), Professor of Anatomy in the University of Manchester.
1911. ‡Smith, Geoffrey W., M.A., F.L.S. New College, Oxford.
1903. *SMITH, Professor H. B. LEES, M.A., M.P. The University, Bristol.
1910. §Smith, H. Bompas, M.A. Victoria University, Manchester.
1889. *SMITH, Sir H. LLEWELLYN, K.C.B., M.A., B.Sc., F.S.S. (Pres. F, 1910.) Board of Trade, S.W.
1860. *Smith, Heywood, M.A., M.D. 40 Portland-court, W.
1876. *Smith, J. Guthrie. 5 Kirklee-gardens, Kelvinside, Glasgow.
1902. ‡Smith, J. Lorrain, M.D., F.R.S., Professor of Pathology in the Victoria University, Manchester.
1903. *Smith, James. Pinewood, Crathes, Aberdeen.
1911. §Smith, Priestley, F.R.C.S., Professor of Ophthalmology in the University of Birmingham. 95 Cornwall-street, Birmingham.

Year of Election.

1910. §Smith, Samuel. Central Library, Sheffield.
1894. §Smith, T. Walrond. Care of Frank Henderson, Esq., 19 Manor-road, Sidcup, Kent.
1910. ‡Smith, W. G., B.Sc., Ph.D. College of Agriculture, Edinburgh.
1896. *Smith, Rev. W. Hodson. 104–122 City-road, E.C.
1911. ‡Smith, W. Parnell. The Grammar School, Portsmouth.
1913. §Smith, Walter Campbell. British Museum (Natural History), Cromwell-road, S.W.
1885. *Smith, Watson. 34 Upper Park-road, Haverstock Hill, N.W.
1909. ‡Smith, William. 218 Sherbrooke-street, Winnipeg, Canada.
1883. ‡SMITHELLS, ARTHUR, B.Sc., F.R.S. (Pres. B, 1907; Local Sec. 1890), Professor of Chemistry in the University of Leeds.
1906. §Smurthwaite, Thomas E., F.R.A.I. 134 Mortimer-road, Kensal Rise, N.W.
1905. ‡Smuts, C. P.O. Box 1088, Johannesburg.
1909. §Smylie, Hugh. 13 Donegall-square North, Belfast.
1857. *SMYTH, JOHN, M.A., F.C.S., F.R.M.S., M.Inst.C.E.I. Milltown, Banbridge, Ireland.
1908. §Smythe, J. A., Ph.D., D.Sc. 10 Queen's-gardens, Benton, Newcastle-on-Tyne.
1888. *SNAPE, H. LLOYD, D.Sc., Ph.D. Balholm, Lathom-road, Southport.
1913. *Snell, J. F. C., M.Inst.C.E. 8 Queen Anne's-gate, S.W.
1905. ‡SODDY, F., M.A., F.R.S. The University, Glasgow.
1905. ‡Sollas, Miss I. B. J., B.Sc. Newnham College, Cambridge.
1879. *SOLLAS, W. J., M.A., Sc.D., F.R.S., F.R.S.E., F.G.S. (Pres. C, 1900; Council, 1900–03), Professor of Geology in the University of Oxford. 173 Woodstock-road, Oxford.
1900. *SOMERVILLE, W., D.Sc., F.L.S., Sibthorpian Professor of Rural Economy in the University of Oxford. 121 Banbury-road, Oxford.
1910. *Sommerville, Duncan M. Y. 70 Argyle-street, St. Andrews, N.B.
1903. ‡Soulby, R. M. Sea Holm, Westbourne-road, Birkdale, Lancashire.
1903. ‡Southall, Henry T. The Graig, Ross, Herefordshire.
1865. *Southall, John Tertius. Parkfields, Ross, Herefordshire.
1883. ‡Spanton, William Dunnett, F.R.C.S. Chatterley House, Hanley, Staffordshire.
1913. §Sparke, Thomas Sparrow. 33 Birkby-crescent, Huddersfield.
1909. ‡Sparling, Rev. J. W., D.D. 159 Kennedy-street, Winnipeg, Canada.
1893. *Speak, John. Kirton Grange, Kirton, near Boston.
1910. ‡Spearman, C. Birnam, Guernsey.
1912. §Speers, Adam, B.Sc., J.P. Holywood, Belfast.
1914. §Spence, Mrs. C. J. The Old Hall, Cheadle, Cheshire.
1910. ‡Spicer, Rev. E. C. The Rectory, Waterstock, Oxford.
1864. *Spicer, Henry, B.A., F.L.S., F.G.S. 14 Aberdeen-park, Highbury, N.
1894. ‡Spiers, A. H. Gresham's School, Holt, Norfolk.
1864. *SPILLER, JOHN, F.C.S. 2 St. Mary's-road, Canonbury, N.
1864. *Spottiswoode, W. Hugh, F.C.S. 6 Middle New-street, Fetter-lane, E.C.
1909. ‡Sprague, D. E. 76 Edmonton-street, Winnipeg, Canada.
1854. *SPRAGUE, THOMAS BOND, M.A., LL.D., F.R.S.E. 29 Buckingham-terrace, Edinburgh.
1888. *Stacy, J. Sargeant. 164 Shoreditch, E.
1903. ‡*Stallworthy, Rev. George B. The Manse, Hindhead, Haslemere, Surrey.*

Year of Election.

1883. *Stanford, Edward, F.R.G.S. 12–14 Long-acre, W.C.
1894. *STANSFIELD, ALFRED, D.Sc. McGill University, Montreal, Canada.
1909. ‡Stansfield, Edgar. Mines Branch, Department of Mines, Ottawa, Canada.
1900. *STANSFIELD, Professor H., D.Sc. Hartley University College, Southampton.
1913. §Stanton, T. E., D.Sc. National Physical Laboratory, Teddington, Middlesex.
1911. §STAPF, Dr. OTTO, F.R.S. Royal Gardens, Kew.
1899. ‡STARLING, E. H., M.D., F.R.S. (Pres. I, 1909), Professor of Physiology in University College, London, W.C.
1898. ‡Stather, J. W., F.G.S. Brookside, Newland Park, Hull.
Staveley, T. K. Ripon, Yorkshire.
1907. §Staynes, Frank. 36–38 Silver-street, Leicester.
1910. ‡*Stead, F. B.* 80 *St. Mary's-mansions, Paddington, W.*
1900. *STEAD, J. E., F.R.S. (Pres. B, 1910.) Laboratory and Assay Office, Middlesbrough.
1881. ‡Stead, W. H. Beech-road, Reigate.
1892. *STEBBING, Rev. THOMAS R. R., M.A., F.R.S. Ephraim Lodge, The Common, Tunbridge Wells.
1896. *STEBBING, W. P. D., F.G.S. 78A Lexham-gardens, W.
1911. ‡Steele, L. J., M.I.E.E. H.M. Dockyard, Portsmouth.
1908. ‡Steele, Lawrence Edward, M.A., M.R.I.A. 18 Crosthwaite-park East, Kingstown, Co. Dublin.
1912. §Steggall, J. E. A., M.A., Professor of Mathematics in University College, Dundee. Woodend, Perth-road, Dundee.
1911. ‡Stein, Sir Marc Aurel, K.C.I.E., D.Sc., D.Litt. Merton College, Oxford.
1909. ‡Steinkopj, Max. 667 Main-street, Winnipeg, Canada.
1884. *Stephens, W. Hudson. Low-Ville, Lewis County, New York, U.S.A.
1902. ‡Stephenson, G. Grianan, Glasnevin, Dublin.
1910. *STEPHENSON, H. K. Banner Cross Hall, Sheffield.
1911. ‡Stern, Moritz. 241 Bristol-road, Birmingham.
1909. ‡Stethern, G. A. Fort Frances, Ontario, Canada.
1908. *Steven, Alfred Ingram, M.A., B.Sc. 50 Onslow-road, Fairfield, Liverpool.
1906. ‡Stevens, Miss C. O. The Plain, Foxcombe Hill, Oxford.
1900. ‡STEVENS, FREDERICK. (Local Sec. 1900.) Town Clerk's Office, Bradford.
1880. *Stevens, J. Edward, LL.B. Le Mayals, Blackpill, R.S.O.
1905. §Stewart, A. F. 127 Isabella-street, Toronto, Canada.
1909. ‡Stewart, David A., M.D. 407 Pritchard-avenue, Winnipeg, Canada.
1875. *Stewart, James, B.A., F.R.C.P.Ed. Junior Constitutional Club, Piccadilly, W.
1901. *Stewart, John Joseph, M.A., B.Sc. 2 Stow Park-crescent, Newport, Monmouthshire.
1901. *Stewart, Thomas. St. George's-chambers, Cape Town.
1911. ‡Stibbs, H. A. Portsea Island Gas Company, Commercial-road, Portsmouth.
1913. *STILES, WALTER. The University, Leeds.
1876. ‡STIRLING, WILLIAM, M.D., D.Sc., F.R.S.E., Professor of Physiology in the Victoria University, Manchester.
1904. ‡Stobbs, J. T. Dunelm, Basford Park, Stoke-on-Trent.
1906. *Stobo, Mrs. Annie. Somerset House, Garelochhead, Dumbartonshire, N.B.

Year of Election.

1901. *Stobo, Thomas. Somerset House, Garelochhead, Dumbartonshire, N.B.
1883. *STOCKER, W. N., M.A. Brasenose College, Oxford.
1898. *Stokes, Professor George J., M.A. 5 Fernhurst-villas, College-road, Cork.
1899. *Stone, Rev. F. J. Radley College, Abingdon.
1874. ‡Stone, J. Harris, M.A., F.L.S., F.C.S. 3 Dr. Johnson's-buildings, Temple, E.C.
1905. ‡Stoneman, Miss Bertha, D.Sc. Huguenot College, Wellington, Cape Province.
1895. *Stoney, Miss Edith A. 20 Reynolds-close, Hampstead Way, N.W.
1908. *Stoney, Miss Florence A., M.D. 4 Nottingham-place, W.
1878. *Stoney, G. Gerald, F.R.S. Oakley, Heaton road, Newcastle-upon-Tyne.
1883. ‡Stopes, Mrs. 7 Denning-road, Hampstead, N.W.
1903. *STOPES, MARIE C., D.Sc., Ph.D., F.L.S. 14 Well-walk, Hampstead, N.W.
1910. §Storey, Gilbert. Department of Agriculture, Cairo.
1887. *Storey, H. L. Bailrigg, Lancaster.
1888. *Stothert, Percy K. Woolley Grange, Bradford-on-Avon, Wilts.
1905. *Stott, Clement H., F.G.S. P.O. Box 7, Pietermaritzburg, Natal.
1881. ‡STRAHAN, AUBREY, M.A., Sc.D., F.R.S., F.G.S. (Pres. C. 1904.) Geological Museum, Jermyn-street, S.W.
1905. ‡Strange, Harold F. P.O. Box 2527, Johannesburg.
1908. *Stratton, F. J. M., M.A. Gonville and Caius College, Cambridge.
1906. *Stromeyer, C. E. 9 Mount-street, Albert-square, Manchester.
1883. §Strong, Henry J., M.D. Colonnade House, The Steyne, Worthing.
1898. *Strong, W. M., M.D. 3 Champion-park, Denmark Hill, S.E.
1887. *Stroud, H., M.A., D.Sc., Professor of Physics in the Armstrong College, Newcastle-upon-Tyne.
1887. *STROUD, WILLIAM, D.Sc., Professor of Physics in the University of Leeds. Care of Messrs. Barr & Stroud, Anniesland, Glasgow.
1876. *Stuart, Charles Maddock, M.A. St. Dunstan's College, Catford, S.E.
1872. *Stuart, Rev. Canon Edward A., M.A. The Precincts, Canterbury.
1885. ‡Stump, Edward C. Malmesbury, Polefield, Blackley, Manchester.
1909. ‡Stupart, R. F. Meteorological Service, Toronto, Canada.
1879. *Styring, Robert. Brinkcliffe Tower, Sheffield
1891. **Sudborough, Professor J. J., Ph.D., D.Sc. University College of Wales, Aberystwyth.*
1902. §Sully, H. T. Scottish Widows-buildings, Bristol.
1898. §Sully, T. N. Avalon House, Queen's-road, Weston-super-Mare.
1911. ‡Summers, A. H., M.A. 16 St. Andrew's-road, Southsea.
1887. *Sumpner, W. E., D.Sc. Technical School, Suffolk-street, Birmingham.
1908. ‡Sutherland, Alexander. School House, Gersa, Watten, Caithness.
1913. §Sutton, A. M. Bucklebury-place, Woolhampton, Berkshire.
1911. §Sutton, Leonard, F.L.S. Hillside, Reading.
1911. ‡Sutton, W. L., F.I.C. Hillcroft, Eaton, Norwich.
1903. ‡Swallow, Rev. R. D., M.A. Chigwell School, Essex.
1881. §SWAN, Sir JOSEPH WILSON, M.A., D.Sc., F.R.S. Overhill, Warlingham, Surrey.
1905. ‡Swan, Miss Mary E. Overhill, Warlingham, Surrey.
1911. *SWANN, Dr. W. F. G. The University, Sheffield.
1897. ‡Swanston, William, F.G.S. Mount Collyer Factory, Belfast.
1913. §Swift, Richard H. 4839 St. Lawrence-avenue, Chicago.

Year of Election.

1887. §Swinburne, James, F.R.S., M.Inst.C.E. 82 Victoria-street, S.W.
1870. *Swinburne, Sir John, Bart. Capheaton Hall, Newcastle-upon-Tyne.
1913. §Swinnerton, H. H. 441 Mansfield-road, Nottingham.
1902. *Sykes, Miss Ella C. Elcombs, Lyndhurst, Hampshire.
1887. *Sykes, George H., M.A., M.Inst.C.E., F.S.A. Glencoe, 64 Elmbourne-road, Tooting Common, S.W.
1913. §Sykes, Godfrey G. Desert Laboratory, Tucson, Arizona, U.S.A.
1896. *Sykes, Mark L., F.R.M.S. 10 Headingley-avenue, Leeds.
1902. *Sykes, Major P. Molesworth, C.M.G. Elcombs, Lyndhurst, Hampshire.
1906 ‡Sykes, T. P., M.A. 4 Gathorne-street, Great Horton, Bradford.
1903. §Symington, Howard W. Brooklands, Market Harborough.
1885. ‡Symington, Johnson, M.D., F.R.S., F.R.S.E. (Pres. H, 1903), Professor of Anatomy in Queen's University, Belfast.
1908. ‡Synnott, Nicholas J. Furness, Naas, Co. Kildare

1910. *Tait, John, M.D., D.Sc. 44 Viewforth-terrace, Edinburgh.
1912. ‡*Talbot, P. Amaury. Abbotsmorton, Inkberrow, Worcestershire.*
1904. §Tallack, H. T. Clovelly, Birdhurst-road, South Croydon.
1913. §Tangye, William. Westmere, Edgbaston Park-road, Birmingham.
1903. *Tanner, Miss Ellen G. Parkside, Corsham, Wilts.
1890. ‡Tanner, H. W. Lloyd, D.Sc., F.R.S. (Local Sec. 1891.) University College, Cardiff.
1892. *Tansley, Arthur G., M.A., F.L.S. Grantchester, near Cambridge.
1908. ‡Tarleton, Francis A., LL.D. 24 Upper Leeson-street, Dublin.
1861. *Tarratt, Henry W. 2c Oxford and Cambridge-mansions, Hyde Park, W.
1902. ‡Tate, Miss. Rantalard, Whitehouse, Belfast.
1913. §Tattersall, W. M. The Museum, The University, Manchester.
1908. ‡Taylor, Rev. Campbell, M.A. United Free Church Manse, Wigtown, Scotland.
1887. ‡Taylor, G. H. Holly House, 235 Eccles New-road, Salford.
1881. *Taylor, H. A. 12 Melbury-road, Kensington, W.
1906. ‡Taylor, H. Dennis. Stancliffe, Mount-villas, York.
1884. *Taylor, H. M., M.A., F.R.S. Trinity College, Cambridge.
1882 *Taylor, Herbert Owen, M.D. Oxford-street, Nottingham.
1913. §Taylor, J. S. The Corinthians, Warwick-road, Acock's Green.
1860. *Taylor, John, M.Inst.C.E. 6 Queen Street-place, E.C.
1906. §Taylor, Miss M. R. Newstead, Blundellsands.
1884. *Taylor, Miss S. Oak House, Shaw, near Oldham.
1894. *Taylor, W. W., M.A. 66 St. John's-road, Oxford.
1901. *Teacher, John H., M.B. 32 Kingsborough-gardens, Glasgow.
1858. ‡Teale, Thomas Pridgin, M.A., F.R.S. 38 Cookridge-street, Leeds.
1885. ‡Teall, J. J. H., M.A., D.Sc., F.R.S., F.G.S. (Pres. C, 1893; Council, 1894–1900, 1909–). Athenæum Club, S.W.
1906. *Teape, Rev. W. M., M.A South Hylton Vicarage, Sunderland.
1910. ‡Tebb, W. Scott, M.A., M.D. 15 Finsbury-circus, E.C.
1879. ‡Temple, Lieutenant G. T., R.N., F.R.G.S. Solheim, Cumberland Park, Acton, W.
1913. §Temple, Sir R. C., Bart., C.I.E. (Pres. H, 1913.) The Nash, Worcester.
1892. *Tesla, Nikola. 45 West 27th-street, New York, U.S.A.
1883. ‡Tetley, C. F. The Brewery, Leeds.
1883. ‡Tetley, Mrs. C. F. The Brewery, Leeds.

Year of
Election.

1882. *THANE, GEORGE DANCER, LL.D., Professor of Anatomy in University College, London, W.C.
1871. ‡THISELTON-DYER, Sir W. T., K.C.M.G., C.I.E., M.A., B.Sc., Ph.D., LL.D., F.R.S., F.L.S. (Pres. D, 1888; Pres. K, 1895; Council, 1885–89, 1895–1900.) The Ferns, Witcombe, Gloucester.
1906. *THODAY, D. The University, Manchester.
1906. *Thoday, Mrs. M. G. 5 Lyme-park, Chinley, Stockport.
1870. ‡Thom, Colonel Robert Wilson, J.P. Brooklands, Lord-street West, Southport.
1891. *Thomas, Miss Clara. Pencerrig, Builth.
1903. *THOMAS, Miss ETHEL N., B.Sc. 3 Downe-mansions, Gondar-gardens, West Hampstead, N.W.
1913. §Thomas, H. H., M.A., B.Sc., F.G.S. 28 Jermyn-street, S.W.
1910. *Thomas, H. Hamshaw. Botany School, Cambridge
1880. *Thomas, Joseph William, F.C.S. Overdale, Shortlands, Kent.
1899. *Thomas, Mrs. J. W. Overdale, Shortlands, Kent.
1902. *Thomas, Miss M. Beatrice. Girton College, Cambridge.
1883. ‡Thomas, Thomas H. 45 The Walk, Cardiff
1904. *Thomas, William, F.R.G.S. Bryn-heulog, Merthyr Tydfil
1891. *Thompson, Beeby, F.C.S., F.G.S. 67 Victoria-road, Northampton.
1888. *Thompson, Claude M., M.A., D.Sc., Professor of Chemistry in University College, Cardiff. 38 Park-place, Cardiff.
1885. ‡THOMPSON, D'ARCY W., C.B., B.A. (Pres. D, 1911; Local Sec., 1912), Professor of Zoology in University College, Dundee.
1896. *Thompson, Edward P. Paulsmoss, Whitchurch, Salop.
1907. *Thompson, Edwin. 25 Sefton-drive, Liverpool.
1883. *Thompson, Francis. Eversley, Haling Park-road, Croydon.
1904. *Thompson, G. R., B.Sc., Principal of and Professor of Mining in the South African School of Mines, Johannesburg.
1912. *Thompson, Rev. H. Percy. Kippington Vicarage, Sevenoaks.
1893. *Thompson, Harry J., M.Inst.C.E. Tregarthen, Garland's-road, Leatherhead.
1883. *Thompson, Henry G., M.D. 7 Heathfield-road, Croydon.
1913. *Thompson, Mrs. Lilian Gilchrist. Kippington Vicarage, Sevenoaks.
1913. §Thompson, Peter. 14 Rotten Park road, Edgbaston, Birmingham.
1876. *Thompson, Richard. Dringcote, The Mount, York.
1913. *Thompson, Sidney Gilchrist. Kippington Vicarage, Sevenoaks.
1876. ‡THOMPSON, SILVANUS PHILLIPS, B.A., D.Sc., F.R.S., F.R.A.S. (Pres. G, 1907; Council, 1897–99, 1910–), Principal of and Professor of Physics in the City and Guilds of London Technical College, Leonard-street, Finsbury, E.C
1883. *Thompson, T. H. Oldfield Lodge, Gray-road, Bowdon, Cheshire.
1896. *THOMPSON, W. H., M.D., D.Sc. (Local Sec. 1908), King's Professor of Institutes of Medicine (Physiology) in Trinity College, Dublin. 14 Hatch-street, Dublin.
1911. ‡Thompson, Mrs. W. H. 328 Assiniboine-avenue, Winnipeg.
1912. ‡Thompson, William Bruce. Thornbank, Dundee.
1912. §Thoms, Alexander. 7 Playfair-terrace, St. Andrews.
1894. ‡THOMSON, ARTHUR, M.A., M.D., Professor of Human Anatomy in the University of Oxford. Exeter College, Oxford.
1913. §Thomson, Arthur W., D.Sc. 23 Craven Hill-gardens, W.
1912. §Thomson, D. C. 'Courier' Buildings, Dundee.
1909. *Thomson, E. 22 Monument-avenue, Swampscott, Mass., U.S.A.
1906. §Thomson, F. Ross, F.G.S. Hensill, Hawkhurst, Kent.
1890. *THOMSON, Professor J. ARTHUR, M.A., F.R.S.E. Castleton House, Old Aberdeen.

Year of Election.

1883. ‡THOMSON, Sir J. J., O.M., M.A., Sc.D., D.Sc., F.R.S. (PRESIDENT, 1909; Pres. A, 1896; Council, 1893–95), Professor of Experimental Physics in the University of Cambridge. Trinity College, Cambridge.
1901. ‡*Thomson, Dr. J. T. Kilpatrick.* 148 *Norfolk-street, Glasgow.*
1889. *Thomson, James, M.A. 22 Wentworth-place, Newcastle-upon-Tyne.
1902. ‡Thomson, James Stuart. 29 Ladysmith-road, Edinburgh.
1891. ‡Thomson, John. Westover, Mount Ephraim-road, Streatham, S.W.
1871. *THOMSON, JOHN MILLAR, LL.D., F.R.S. (Council, 1895–1901), Professor of Chemistry in King's College, London. 18 Lansdowne-road, Holland Park, W.
1874. §THOMSON, WILLIAM, F.R.S.E., F.C.S. Royal Institution, Manchester.
1880. §Thomson, William J. Ghyllbank, St. Helens.
1906. ‡Thornely, Miss A. M. M. Oaklands, Langham-road, Bowdon, Cheshire.
1905. *Thornely, Miss L. R. Nunclose, Grassendale, Liverpool.
1898. *THORNTON, W. M., D.Sc., Professor of Electrical Engineering in the Armstrong College, Newcastle-on-Tyne.
1902. ‡Thornycroft, Sir John I., F.R.S., M.Inst.C.E. Eyot Villa, Chiswick Mall, W.
1903. ‡Thorp, Edward. 87 Southbank-road, Southport.
1881. ‡Thorp, Fielden. Blossom-street, York.
1881. *Thorp, Josiah. 24 Manville-road, New Brighton, Cheshire.
1898. §Thorp, Thomas. Moss Bank, Whitefield, Manchester.
1898. ‡THORPE, JOCELYN FIELD, Ph.D., F.R.S. Sheffield University.
1871. ‡THORPE, Sir T. E., C.B., Ph.D., LL.D., F.R.S., F.R.S.E., F.C.S. (Pres. B, 1890; Council, 1886–92.) Whinfield, Salcombe, South Devon.
1899. §THRELFALL, RICHARD, M.A., F.R.S. Oakhurst, Church-road, Edgbaston, Birmingham.
1896. §THRIFT, WILLIAM EDWARD, M.A. (Local Sec. 1908), Professor of Natural and Experimental Philosophy in the University of Dublin. 80 Grosvenor-square, Rathmines, Dublin.
1907. ‡*Thwaites, R. E.* 28 *West-street, Leicester.*
1889. ‡Thys, Colonel Albert. 9 Rue Briderode, Brussels.
1873. *TIDDEMAN, R. H., M.A., F.G.S. 298 Woodstock-road, Oxford.
1905. ‡Tietz, Heinrich, B.A., Ph.D. South African College, Cape Town.
1874. ‡TILDEN, Sir WILLIAM A., D.Sc., F.R.S., F.C.S. (Pres. B, 1888; Council, 1898–1904.) The Oaks, Northwood, Middlesex.
1913. §Tilley, J. W. Field House, Harborne, Park-road, Birmingham.
1899. ‡Tims, H. W. Marett, M.A., M.D., F.L.S. 7 Sussex-gardens, Hyde Park, W.
1902. ‡Tipper, Charles J. R., B.Sc. 21 Greenside, Kendal.
1905. ‡Tippett, A. M., M.Inst.C.E. Cape Government Railways, Cape Town.
1911. §Tizard, Henry T. Oriel College, Oxford.
1900. *Tocher, J. F., D.Sc., F.I.C. Crown-mansions, 41½ Union-street, Aberdeen.
1912. §Todd, John A. The Nook, Alexandra Park, Nottingham.
1907. ‡Todd, Professor J. L. MacDonald College, Quebec, Canada.
1889. §Toll, John M. 49 Newsham-drive, Liverpool.
1875. ‡Torr, Charles Hawley. 35 Burlington-road, Sherwood, Nottingham.
1909. ‡Tory, H. M. Edmonton, Alberta, Canada.

Year of Election.

1912. ‡Tosh, Elmslie. 11 Reform-street, Dundee.
1901. ‡Townsend, J. S., M.A., F.R.S., Professor of Physics in the University of Oxford. New College, Oxford.
1876. *Trail, J. W. H., M.A., M.D., F.R.S., F.L.S. (Pres. K, 1910), Regius Professor of Botany in the University of Aberdeen.
1883. ‡Traill, A., M.D., LL.D., Provost of Trinity College, Dublin, Ballylough, Bushmills, Ireland.
1870. ‡Traill, William A. Giant's Causeway Electric Tramway, Portrush, Ireland.
1902. ‡*Travers, Ernest J. Dunmurry, Co. Antrim.*
1884. ‡Trechmann, Charles O., Ph.D., F.G.S. Hartlepool.
1908. §Treen, Rev. Henry M., B.Sc. Wicken, Soham, Cambridge.
1908. ‡Tremain, Miss Caroline P., B.A. Alexandra College, Dublin.
1910. §Tremearne, Major A. J. N., B.A. 105 Blackheath Park, S.E.
1911. §Tremearne, Mrs., LL.A. 105 Blackheath Park, S.E.
1887. *Trench-Gascoigne, Mrs. F. R. Lotherton Hall, Parlington, Aberford, Leeds.
1903. ‡Trenchard, Hugh. The Firs, Clay Hill, Enfield.
1908. ‡Tresilian, R. S. Cumnor, Eglington-road, Dublin.
1905. ‡Trevor-Battye, A., M.A., F.L.S., F.R.G.S. Stoner Hill, Petersfield, Hants.
1871. ‡Trimen, Roland, M.A., F.R.S., F.L.S., F.Z.S. Fawley, Onslow-crescent, Woking.
1902 ‡Tristram, Rev. J. F., M.A., B.Sc. 20 Chandos-road, Chorlton-cum-Hardy, Manchester.
1884. *Trotter, Alexander Pelham. 8 Richmond-terrace, Whitehall, S.W.
1887. *Trouton, Frederick T., M.A., Sc.D., F.R.S. (Council, 1911-), Professor of Physics in University College, W.C.
1898. *Trow, Albert Howard, D.Sc., F.L.S., Professor of Botany in University College, Cardiff.
1913. §Tschugaeff, Professor L. The University, St. Petersburg.
1885. *Tubby, A. H., M.S., F.R.C.S. 68 Harley-street, W.
1847. *Tuckett, Francis Fox. Frenchay, Bristol.
1905. §Turmeau, Charles. Claremont, Victoria Park, Wavertree, Liverpool.
1912. ‡Turnbull, John. City Chambers, Dundee.
1901. §Turnbull, Robert, B.Sc. Department of Agriculture and Technical Instruction, Dublin.
1893. ‡Turner, Dawson, M.D., F.R.S.E. 37 George-square, Edinburgh.
1913. §Turner, G. M. Kenilworth.
1894. *Turner, H. H., M.A., D.Sc., F.R.S., F.R.A.S. (General Secretary, 1913- ; Pres. A, 1911), Professor of Astronomy in the University of Oxford. The Observatory, Oxford.
1905. ‡Turner, Rev. Thomas. St. Saviour's Vicarage, 50 Fitzroy-street, W.
1886. *Turner, Thomas, M.Sc., A.R.S.M., F.I.C., Professor of Metallurgy in the University of Birmingham. Springfields, Upland-road, Selly Hill, Birmingham.
1863. *Turner, Sir William, K.C.B., LL.D., D.C.L., F.R.S., F.R.S.E. (President, 1900; Pres. H, 1889, 1897), Principal of the University of Edinburgh. 6 Eton-terrace, Edinburgh.
1910. §Turner, W. E. S. The University, Sheffield.
1890. *Turpin, G. S., M.A., D.Sc. High School, Nottingham.
1907. §Tutton, A. E. H., M.A., D.Sc., F.R.S. (Council, 1908-12.) Duart, Yelverton, South Devon.
1886. *Twigg, G. H. 1 & 2 Ludgate-hill, Birmingham.
1899. ‡Twisden, John R., M.A. 14 Gray's Inn-square, W.C.

Year of Election.

1907. §Twyman, F. 75A Camden-road, N.W.
1865. ‡Tylor, Sir Edward Burnett, D.C.L., LL.D., F.R.S. (Pres. H., 1884; Council, 1896–1902.) Linden, Wellington, Somerset.
1911. *Tyndall, A. M., M.Sc. The University, Bristol.
1883. ‡Tyrer, Thomas, F.C.S. Stirling Chemical Works, Abbey-lane, Stratford, E.
1912. ‡Tyrrell, G. W. Geological Department, The University, Glasgow.

1884. *Underhill, G. E., M.A Magdalen College, Oxford.
1903. ‡Underwood, Captain J. C 60 Scarisbrick New-road, Southport.
1908. §Unwin, Ernest Ewart, M.Sc. Grove House, Leighton Park School, Reading.
1883. §Unwin, John. Eastcliffe Lodge, Southport.
1876. *Unwin, W. C., F.R.S., Pres.Inst.C.E. (Pres. G, 1892; Council, 1892–99.) 7 Palace Gate-mansions, Kensington, W.
1909. ‡Urquhart, C. 239 Smith-street, Winnipeg, Canada.
1880. ‡Ussher, W. A. E., F.G.S. 28 Jermyn-street, S.W.
1905. ‡Uttley, E. A., Electrical Inspector to the Rhodesian Government, Bulawayo.

1887. *Valentine, Miss Anne. The Elms, Hale, near Altrincham.
1912. §Valentine, C. W. 103 Magdalen-green, Dundee.
1908. ‡Valera, Edward de. University College, Blackrock, Dublin.
1865. *Varley, S. Alfred. Arrow Works, Jackson-road, Holloway, N.
1907. §Varley, W. Mansergh, M.A., D.Sc., Ph.D. Morningside, Eaton-crescent, Swansea.
1903. ‡Varwell, H. B. Sittaford, West-avenue, Exeter.
1909. *Vassall, H., M.A. The Priory, Repton, Burton-on-Trent.
1907. §Vaughan, Arthur, M.A., D.Sc., F.G.S., Lecturer in Geology at the University of Oxford. The Museums, Oxford.
1905. ‡Vaughan, E. L. Eton College, Windsor.
1913. §Vaughton, T. A. Livery-street, Birmingham.
1881. ‡Veley, V. H., M.A., D.Sc., F.R.S. 8 Marlborough-place, St. John's Wood, N.W.
1883. *Verney, Lady. Plâs Rhoscolyn, Holyhead.
1904. *Vernon, H. M., M.A., M.D. 5 Park Town, Oxford.
1896. *Vernon, Thomas T. Shotwick Park, Chester.
1896. *Vernon, William. Shotwick Park, Chester.
1890. *Villamil, Lieut.-Colonel R. de, R.E. Carlisle Lodge, Rickmansworth.
1906. *Vincent, J. H., M.A., D.Sc. L.C.C. Paddington Technical Institute, Saltram-crescent, W.
1899. *Vincent, Swale, M.D., D.Sc. (Local Sec. 1909), Professor of Physiology in the University of Manitoba, Winnipeg, Canada.
1883. *Vines, Sydney Howard, M.A., D.Sc., F.R.S., F.L.S. (Pres. K, 1900; Council, 1894–97), Professor of Botany in the University of Oxford. Headington Hill, Oxford.
1902. ‡Vinycomb, T. B. Sinn Fein, Shooters Hill, S.E.
1888. *Vogt, Mrs. 478 Uxbridge-road, W.
1904. §Volterra, Professor Vito. Regia Universita, Rome.

1904. §Wace. A. J. B. Pembroke College, Cambridge.
1902. ‡Waddell, Rev. C. H. The Vicarage, Grey Abbey, Co. Down.
1909. ‡Wadge, Herbert W., M.D. 754 Logan-avenue, Winnipeg, Canada
1888. ‡Wadworth, H. A. Breinton Court, near Hereford.

Year of
Election.

1890. §Wager, Harold W. T., F.R.S., F.L.S. (Pres. K, 1905.) Hendre, Horsforth-lane, Far Headingley, Leeds.
1900. ‡Wagstaff, C. J. L., B.A. Haberdashers' School, Cricklewood, N.W.
1902. ‡Wainwright, Joel. Finchwood, Marple Bridge, Stockport
1906. ‡Wakefield, Charles. Heslington House, York.
1905. §Wakefield, Captain E. W. Stricklandgate House, Kendal.
1894. ‡Walford, Edwin A., F.G.S. 21 West Bar, Banbury.
1882. *Walkden, Samuel, F.R.Met.S. Care of George Lloyd, Esq., 7 Coper's Cope-road, Beckenham, Kent.
1893. ‡Walker, Alfred O., F.L.S. Ulcombe-place, Maidstone, Kent.
1890. ‡Walker, A. Tannett. The Elms, Weetwood, Leeds.
1901 *Walker, Archibald, M.A., F.I.C. Newark Castle, Ayr, N.B.
1897. *Walker, Sir Edmund, C.V.O., D.C.L., F.G.S. (Local Sec. 1897.) Canadian Bank of Commerce, Toronto, Canada.
1904. §Walker, E. R. Nightingales, Adlington, Lancashire.
1911. *Walker, E. W. Ainley, M.A. University College, Oxford.
1905. ‡Walker, Mrs. Ainley. 31 Holywell, Oxford.
1891. ‡Walker, Frederick W. Tannett. Carr Manor, Meanwood, Leeds.
1894. *Walker, G. T., M.A., D.Sc., F.R.S., F.R.A.S. Red Roof, Simla, India.
1897. ‡Walker, George Blake, M.Inst.C.E. Tankersley Grange, near Barnsley.
1913. §Walker, George W., F.R.S. 63 Lensfield-road, Cambridge.
1906. ‡Walker, J. F. E. Gelson, B.A. 45 Bootham, York.
1894. *Walker, James, M.A. 30 Norham-gardens, Oxford.
1910. *Walker, James, D.Sc., F.R.S. (Pres. B, 1911), Professor of Chemistry in the University of Edinburgh. 5 Wester Coates-road, Edinburgh.
1906. §Walker, Dr. Jamieson. 37 Charnwood-street, Derby.
1909. ‡Walker, Lewie D. Lieberose, Monteith-road, Cathcart, Glasgow.
1907. ‡Walker, Philip F., F.R.G.S. 36 Prince's-gardens, S.W.
1909. §Walker, Mrs. R. 3 Riviera-terrace, Rushbrooke, Queenstown, Co. Cork.
1908. *Walker, Robert. Ormidale, Combe Down, Bath.
1888. ‡Walker, Sydney F. 1 Bloomfield-crescent, Bath.
1896. §Walker, Colonel William Hall, M.P. Gateacre, Liverpool.
1910. ‡Wall, G. P., F.G.S. 32 Collegiate-crescent, Sheffield.
1883. ‡Wall, Henry. 14 Park-road, Southport.
1911. §Wall, Thomas F., D.Sc., Assoc.M.Inst.C.E. The University, Birmingham.
1905. ‡Wallace, R. W. 2 Harcourt-buildings, Temple, E.C.
1901. ‡Wallace, William, M.A., M.D. 25 Newton-place, Glasgow.
1887. *Waller, Augustus D., M.D., F.R.S. (Pres. I, 1907.) 32 Grove End-road, N.W.
1905. §Waller, Mrs. 32 Grove End-road, N.W.
1913. *Waller, J. C, B.A. 32 Grove End-road, N.W.
1913. *Waller, Miss M. D., B.Sc., 32 Grove End-road, N.W.
1913. *Waller, W. W., B.A., 32 Grove End-road, N.W.
1889. *Wallis, Arnold J., M.A., Corpus Christi College, Cambridge.
1895. ‡Wallis, E. White, F.S.S. Royal Sanitary Institute and Parkes Museum, 90 Buckingham Palace-road, S.W.
1894. *Walmisley, A. T., M.Inst.C.E. 9 Victoria-street, Westminster, S.W.
1891. §Walmsley, R. M., D.Sc. Northampton Institute, Clerkenwell, E.C.
1903. ‡Walsh, W. T. H. Kent Education Committee, Caxton House, Westminster, S.W.
1895. ‡Walsingham, The Right Hon. Lord, LL.D., F.R.S. Merton Hall, Thetford.

Year of Election.

1902. *Walter, Miss L. Edna. 38 Woodberry-grove, Finsbury Park, N.
1904. *Walters, William, jun. Albert House, Newmarket.
1887. ‡WARD, Sir A. W., M.A., Litt.D., Master of Peterhouse, Cambridge.
1911. ‡Ward, A. W. Town Hall, Portsmouth.
1881. §Ward, George, F.C.S. Buckingham-terrace, Headingley, Leeds.
1905. ‡Warlow, Dr. G. P. 15 Hamilton-square, Birkenhead.
1884. *Warner, James D. 199 Baltic-street, Brooklyn, U.S.A.
1887. ‡WARREN, General Sir CHARLES, R.E., K.C.B., G.C.M.G., F.R.S., F.R.G.S. (Pres E, 1887.) Athenæum Club, S.W.
1913. §Warren, William Henry, LL.D., M.Sc., M.Inst.C.E., Challis Professor of Engineering in the University of Sydney, New South Wales, Australia.
1913. §Warton, Lieut.-Colonel R. G. St. Helier's, Jersey.
1875. *WATERHOUSE, Major-General J. Hurstmead, Eltham, Kent.
1905. ‡Watermeyer, F. S., Government Land Surveyor. P.O. Box 973, Pretoria, South Africa.
1900. ‡Waterston, David, M.D., F.R.S.E. King's College, Strand, W.C.
1909. §Watkinson, Professor W. H. The University, Liverpool.
1884. ‡Watson, A. G., D.C.L. Uplands, Wadhurst, Sussex.
1901. *WATSON, ARNOLD THOMAS, F.L.S. Southwold, Tapton Crescent-road, Sheffield.
1886. *Watson, C. J. Alton Cottage, Botteville-road, Acock's Green, Birmingham.
1909. §WATSON, Colonel Sir C. M., K.C.M.G., C.B., R.E., M.A. (Pres. E, 1912.) 16 Wilton-crescent, S.W.
1906. ‡Watson, D. M. S. University College, London, W.C.
1909. ‡Watson, Ernest Ansley, B.Sc. Alton Cottage, Botteville-road, Acock's Green, Birmingham.
1892. ‡Watson, G., M.Inst.C.E. 5 Ruskin-close, Hampstead-way, N.W.
1885. ‡Watson, Deputy Surgeon-General G. A. Hendre, Overton Park, Cheltenham.
1906. *Watson, Henry Angus. 3 Museum-street, York.
1913. §Watson, John D., M.Inst.C.E. Tyburn, Birmingham.
1894. *WATSON, Professor W., D.Sc., F.R.S. 7 Upper Cheyne-row, S.W.
1879. *WATSON, WILLIAM HENRY, F.C.S., F.G.S. Braystones House, Beckermet, Cumberland.
1901. ‡Watt, Harry Anderson, M.P. Ardenslate House, Hunter's Quay, Argyllshire.
1913. *Watt, James. 28 Charlotte-square, Edinburgh.
1875. *WATTS, JOHN, B.A., D.Sc. Merton College, Oxford.
1873. *WATTS, W. MARSHALL, D.Sc. Shirley, Venner-road, Sydenham, S.E.
1883. *WATTS, W. W., M.A., M.Sc., F.R.S., F.G.S. (Pres. C, 1903; Council, 1902-09), Professor of Geology in the Imperial College of Science and Technology, London, S.W.
1870. §Watts, William, M.Inst.C.E., F.G.S. Kenmore, Wilmslow, Cheshire.
1911. §Waxweiler, Professor E. Solvay Institute, Brussels.
1905. ‡Way, W. A., M.A. The College, Graaf Reinet, South Africa.
1907. ‡Webb, Wilfred Mark, F.L.S. Odstock, Hanwell, W.
1910. ‡Webster, Professor Arthur G. Worcester, Massachusetts, U.S.A.
1909. ‡Webster, William, M.D. 1252 Portage-avenue, Winnipeg, Canada.
1908. §Wedderburn, Ernest Maclagan, F.R.S.E. 7 Dean Park-crescent, Edinburgh.
1903. ‡Weekes, R. W., A.M.Inst.C.E. 65 Hayes-road, Bromley, Kent.
1890. *WEISS, F. ERNEST, D.Sc., F.L.S. (Pres. K, 1911), Professor of Botany in the Victoria University, Manchester.

Year of Election

1905. ‡Welby, Miss F. A. Hamilton House, Hall-road, N.W.
1902. ‡Welch, R. J. 49 Lonsdale-street, Belfast.
1894. ‡Weld, Miss. 119 Iffley-road, Oxford.
1880. *Weldon, Mrs. Merton Lea, Oxford.
1908. ‡Welland, Rev. C. N. Wood Park, Kingstown, Co. Dublin.
1881. §Wellcome, Henry S. Snow Hill-buildings, E.C.
1911. ‡WELLDON, Right Rev. J. E. C., D.D. (Pres. L, 1911.) The Deanery, Manchester.
1908. ‡*Wellisch, E. M. 17 Park-street, Cambridge.*
1881. ‡Wells, Rev. Edward, M.A. West Dean Rectory, Salisbury.
1911. *WELSFORD, Miss E. J. Imperial College of Science, S.W.
Wentworth, Frederick W. T. Vernon. Wentworth Castle, near Barnsley, Yorkshire.
1864. *Were, Anthony Berwick. The Limes, Walland's Park, Lewes.
1886. *Wertheimer, Julius, D.Sc., B.A., F.I.C., Dean of the Faculty of Engineering in the University of Bristol.
1910. §WEST, G. S., M.A., D.Sc., Professor of Botany in the University of Birmingham.
1900. §WEST, WILLIAM, F.L.S. 26 Woodville-terrace, Horton-lane Bradford.
1903. §Westaway, F. W. 1 Pemberley-crescent, Bedford.
1882. *Westlake, Ernest, F.G.S. Fordingbridge, Salisbury.
1900. ‡Wethey, E. R., M.A., F.R.G.S. 4 Cunliffe-villas, Manningham, Bradford.
1909. ‡Wheeler, A. O., F.R.G.S. The Alpine Club of Canada, Sidney, B.C., Canada.
1878. *Wheeler, W. H., M.Inst.C.E. 4 Hope-park, Bromley, Kent.
1893. *WHETHAM, W. C. D., M.A., F.R.S. Upwater Lodge, Cambridge.
1888. ‡Whidborne, Miss Alice Maria. Charanté, Torquay.
1912. §Whiddington, R., M.A., D.Sc. St. John's College, Cambridge.
1913. §Whipp, E. M. 14 St. George's-road, St. Anne's-on-Sea.
1912. *Whipple, F. J., M.A. Meteorological Office, South Kensington, S.W.
1898. *WHIPPLE, ROBERT S. Scientific Instrument Company, Cambridge.
1859. *WHITAKER, WILLIAM, B.A., F.R.S., F.G.S. (Pres. C, 1895; Council, 1890–96.) 3 Campden-road, Croydon.
1884. ‡Whitcher, Arthur Henry. Dominion Lands Office, Winnipeg, Canada.
1897. ‡Whitcombe, George. The Wotton Elms, Wotton, Gloucester.
1886. ‡WHITE, A. SILVA. Clarendon Lodge, St. John's-gardens, Holland Park, W.
1908. ‡White, Mrs. A. Silva. Clarendon Lodge, St. John's-gardens, Holland Park, W.
1911. ‡White, Miss E. L., M.A. Day Training College, Portsmouth.
1913. §White, Mrs. E. W. Anelgate, Harborne-road, Edgbaston, Birmingham.
1904. ‡White, H. Lawrence, B.A. 33 Rossington-road, Sheffield.
1885. *White, J. Martin. Balruddery, Dundee.
1910. *White, Mrs. Jessie, D.Sc., B.A. 49 Gordon-mansions, W.C.
1912. §White, R. G., M.Sc. University College, Bangor, North Wales.
1877. *White, William. 20 Hillersdon-avenue, Church-road, Barnes, S.W.
1904. ‡WHITEHEAD, J. E. L., M.A. (Local Sec. 1904.) Guildhall, Cambridge.
1913. §Whitehouse, Richard H., M.Sc. Queen's University, Belfast.
1905. ‡Whiteley, Miss M. A., D.Sc. Imperial College of Science and Technology, S.W.
1893. §Whiteley, R. Lloyd, F.C.S., F.I.C. Municipal Science and Technical School, West Bromwich.

Year of Election.

1907. *Whitley, E. 13 Linton-road, Oxford.
1905. *Whitmee, H. B. P.O. Box 470, Durban, Natal.
1891. ‡Whitmell, Charles T., M.A., B.Sc. Invermay, Hyde Park, Leeds.
1897. ‡WHITTAKER, E. T., M.A., F.R.S., Professor of Mathematics in the University of Edinburgh.
1901. ‡Whitton, James. City Chambers, Glasgow.
1905. §Wibberley, C., M.V.O. Solheim, Branstone-road, Kew Gardens, Surrey.
1913. §WICKSTEED, Rev. PHILIP H., M.A. (Pres. F, 1913.) Childrey, Wantage, Berkshire.
1912. §Wight, Dr. J. Sherman. 30 Schermerhorn-street, Brooklyn, U.S.A.
1889. *WILBERFORCE, L. R., M.A., Professor of Physics in the University of Liverpool.
1887. *WILDE, HENRY, D.Sc., D.C.L., F.R.S. The Hurst, Alderley Edge, Cheshire.
1910. §Wilkins, C. F. Lower Division, Eastern Jumna Canal, Delhi.
1905. ‡Wilkins, R. F. Thatched House Club, St. James's-street, S.W.
1904. §Wilkinson, Hon. Mrs. Dringhouses Manor, York.
1900. §Wilkinson, J. B. Holme-lane, Dudley Hill, Bradford.
1886. *Wilkinson, J. H. Ashfurlong Hall, Sutton Coldfield.
1913. §Willcox, J. Edward, M.Inst.C.E. 27 Calthorpe-road, Edgbaston, Birmingham.
1903 ‡Willett, John E. 3 Park-road, Southport.
1904. *Williams, Miss Antonia. 6 Sloane-gardens, S.W.
1905. §Williams, Gardner F. 2201 R-street, Washington, D.C., U.S.A.
1883. ‡Williams, Rev. H. Alban, M.A. Sheering Rectory, Harlow, Essex.
1861. *Williams, Harry Samuel, M.A., F.R.A.S. 6 Heathfield, Swansea.
1875. *Williams, Rev. Herbert Addams. Llangibby Rectory, near Newport, Monmouthshire.
1891. §Williams, J. A. B., M.Inst.C.E. Bloomfield, Branksome Park, Bournemouth.
1883. *Williams, Mrs. J. Davies. 5 Chepstow-mansions, Bayswater, W.
1888. *Williams, Miss Katharine T. Llandaff House, Pembroke-vale, Clifton, Bristol.
1901. *Williams, Miss Mary. 6 Sloane-gardens, S.W.
1891. ‡Williams, Morgan. 5 Park-place, Cardiff.
1883. ‡Williams, T. H. 27 Water-street, Liverpool.
1877. *WILLIAMS, W. CARLETON, F.C.S. Broomgrove, Goring-on-Thames.
1906. ‡*Williams, W. F. Lobb. 32 Lowndes-street, S.W.*
1857. ‡WILLIAMSON, BENJAMIN, M.A., D.C.L., F.R.S. Trinity College, Dublin.
1894. *Williamson, Mrs. Janora. 18 Rosebery-gardens, Crouch End, N.
1910. ‡Williamson, K. B., Central Provinces, India. Care of Messrs. Grindlay & Co., 54 Parliament-street, S.W.
1913. §Willink, H. G. Hillfields, Burghfield, Mortimer, Berkshire.
1895. ‡WILLINK, W. (Local Sec. 1896.) 14 Castle-street, Liverpool.
1895. ‡WILLIS, JOHN C., M.A., F.L.S. Jardin Botanico, Rio de Janeiro.
1896. ‡WILLISON, J. S. (Local Sec. 1897.) Toronto, Canada.
1913. *Wills, L. J., M.A., F.G.S. The University, Birmingham.
1899. §Willson, George. Lendarac, Sedlescombe-road, St. Leonards-on-Sea.
1899. §Willson, Mrs. George. Lendarac, Sedlescombe-road, St. Leonards-on-Sea.
1913. §Wilmore, Albert, D.Sc., F.G.S. Fernbank, Colne.
1911. *Wilmott, A. J., B.A. Natural History Museum, S.W.

Year of Election

1911. §Wilsmore, Professor N. T. M. The University, Perth, Western Australia.
1911. §Wilsmore, Mrs. The University, Perth, Western Australia.
1908. §Wilson, Miss. Glenfield, Deighton, Huddersfield.
1901. ‡Wilson, A. Belvoir Park, Newtownbreda, Co. Down.
1878. ‡Wilson, Professor Alexander S., M.A., B.Sc. United Free Church Manse, North Queensferry.
1905. ‡Wilson, A. W. P.O. Box 24, Langlaagte, South Africa.
1907. §Wilson, A. W. Low Slack, Queen's-road, Kendal.
1903. ‡Wilson, C. T. R., M.A., F.R.S. Sidney Sussex College, Cambridge.
1894. *Wilson, Charles J., F.I.C., F.C.S. 14 Suffolk-street, Pall Mall, S.W.
1904. §Wilson, Charles John, F.R.G.S. Deanfield, Hawick, Scotland.
1912. §Wilson, David, M.A., D.Sc. Carbeth, Killearn, N.B.
1904. §Wilson, David, M.D. Glenfield, Deighton, Huddersfield.
1912. *Wilson, David Alec. 1 Broomfield-road, Ayr.
1900. *Wilson, Duncan R. 44 Whitehall-court, S.W.
1895. ‡Wilson, Dr. Gregg. Queen's University, Belfast.
1901. ‡Wilson, Harold A., M.A., D.Sc., F.R.S., Professor of Physics in the Rice Institute, Houston, Texas.
1902. *Wilson, Harry, F.I.C. 32 Westwood-road, Southampton.
1879. ‡Wilson, Henry J., M.P. Osgathorpe Hills, Sheffield.
1910. *Wilson, J. S. 29 Denbigh-street, S.W.
1913. §Wilson, Professor J. T., F.R.S. University of Sydney, Sydney, N.S.W.
1908. §Wilson, Professor James, M.A., B.Sc. 40 St. Kevin's-park, Dartry-road, Dublin.
1879. ‡Wilson, John Wycliffe. Easthill, East Bank-road, Sheffield.
1901. *Wilson, Joseph. Hillside, Avon-road, Walthamstow, N.E.
1908. *Wilson, Malcolm, D.Sc., F.L.S., Lecturer in Mycology and Bacteriology in the University of Edinburgh. Royal Botanic Gardens, Edinburgh.
1909. §Wilson, R. A. Hinton, Londonderry.
1847. *Wilson, Rev. Sumner. Preston Candover Vicarage, Basingstoke.
1883. ‡Wilson, T. Rivers Lodge, Harpenden, Hertfordshire.
1892. ‡Wilson, T. Stacey, M.D. 27 Wheeley's-road, Edgbaston, Birmingham.
1861. ‡Wilson, Thomas Bright. Ghyllside, Wells-road, Ilkley, Yorkshire.
1887. §Wilson, W. Battlehillock, Kildrummy, Mossat, Aberdeenshire.
1909. ‡Wilson, W. Murray. 29 South Drive, Harrogate.
1910. §Wilton, T. R., M.A., Assoc.M.Inst.C.E. 18 Westminster-chambers, Crosshall-street, Liverpool.
1907. §Wimperis, H. E., M.A. 16 Reynolds-close, Hampstead-way, N.W.
1910. ‡Winder, B. W. Ceylon House, Sheffield.
1886. ‡WINDLE, Sir BERTRAM C. A., M.A., M.D., D.Sc., F.R.S., President of University College, Cork.
1863. *WINWOOD, Rev. H. H., M.A., F.G.S. (Local Sec. 1864.) 11 Cavendish-crescent, Bath.
1905. §Wiseman, J. G., F.R.C.S., F.R.G.S. Stranraer, St. Peter's-road, St. Margaret's-on-Thames.
1913. §Wohlgmuth, Dr. A. 44 Church-crescent, Muswell Hill, N.
1875. ‡WOLFE-BARRY, Sir JOHN, K.C.B., F.R.S., M.Inst.C.E. (Pres. G, 1898; Council, 1899–1903, 1909–10.) Delahay House, 15 Chelsea Embankment, S.W.
1905. ‡Wood, A., jun. Emmanuel College, Cambridge.
1863. *Wood, Collingwood L. Freeland, Forgandenny, N.B.

Year of Election.

1875. *Wood, George William Rayner. Singleton Lodge, Manchester.
1878. ‡Wood, Sir H. Trueman, M.A. Royal Society of Arts, John-street, Adelphi, W.C.; and Prince Edward's-mansions, Bayswater, W.
1908. ‡Wood, Sir Henry J. 4 Elsworthy-road, N.W.
1883. *Wood, J. H. 21 Westbourne-road, Birkdale, Lancashire.
1912. §Wood, John K. 304 Blackness-road, Dundee.
1904. *Wood, T. B., M.A. (Pres. M, 1913), Professor of Agriculture in the University of Cambridge. Caius College, Cambridge.
1899. *Wood, W. Hoffman. Ben Rhydding, Yorkshire.
1901. *Wood, William James, F.S.A.(Scot.). 266 George-street, Glasgow.
1899. *Woodcock, Mrs. A. Care of Messrs. Stilwell & Harley, 4 St. James'-street, Dover.
1896. *Woodhead, Professor G. Sims, M.D. Pathological Laboratory, Cambridge.
1911. §Woodhead, T. W., Ph.D., F.L.S. Technical College, Huddersfield.
1912. *Wood-Jones, F., D.Sc. New Selma, Epsom, Surrey.
1906. *Woodland, Dr. W. N. F. Zoological Department, The Muir Central College, Allahabad, United Provinces, India.
1904. §Woodrow, John. Berryknowe, Meikleriggs, Paisley.
1904. ‡Woods, Henry, M.A. Sedgwick Museum, Cambridge.
Woods, Samuel. 1 Drapers'-gardens, Throgmorton-street, E.C.
1887. *Woodward, Arthur Smith, LL.D., F.R.S., F.L.S., F.G.S. (Pres. C, 1909; Council, 1903–10), Keeper of the Department of Geology, British Museum (Natural History), Cromwell-road, S.W.
1869. *Woodward, C. J., B.Sc., F.G.S. The Lindens, St. Mary's-road, Harborne, Birmingham.
1912. §Woodward, Mrs. C. J. The Lindens, St. Mary's-road, Harborne, Birmingham.
1886. ‡Woodward, Harry Page, F.G.S. 129 Beaufort-street, S.W.
1866. ‡Woodward, Henry, LL.D., F.R.S., F.G.S. (Pres. C, 1887; Council, 1887–94.) 13 Arundel-gardens, Notting Hill, W
1870. ‡Woodward, Horace B., F.R.S., F.G.S. 85 Coombe-road, Croydon.
1894. *Woodward, John Harold. 8 Queen Anne's-gate, Westminster S.W.
1909. *Woodward, Robert S. Carnegie Institution, Washington, U.S.A.
1908. §Woolacott, David, D.Sc., F.G.S. 8 The Oaks West, Sunderland.
1890. *Woollcombe, Robert Lloyd, M.A., LL.D., F.I.Inst., F.R.C.Inst., F.R.G.S., F.R.E.S., F.S.S., M.R.I.A. 14 Waterloo-road, Dublin.
1883. *Woolley, George Stephen. Victoria Bridge, Manchester.
1912. *Wordie, James M., B.A. St. John's College, Cambridge.
1908. ‡*Worsdell, W. C. 2 Woodside, Bathford, Bath.*
1863. *Worsley, Philip J. Rodney Lodge, Clifton, Bristol.
1901. ‡Worth, J. T. Oakenrod Mount, Rochdale.
1904. ‡Worthington, A. M., C.B., F.R.S. 5 Louisa-terrace, Exmouth.
1908. *Worthington, James H., M.A., F.R.A.S., F.R.G.S. The Observatory, Four-Marks, Alton.
1906. ‡Wragge, R. H. Vernon. York.
1910. ‡Wrench, E. G. Park Lodge, Baslow, Derbyshire.
1906. ‡Wright, Sir A. E., M.D., D.Sc., F.R.S. 6 Park-crescent, W.
1883. *Wright, Rev. Arthur, D.D. Queens' College, Cambridge.
1909. ‡Wright, C. S., B.A. Caius College, Cambridge.
1905. **Wright, FitzHerbert. The Hayes, Alfreton.*
1874. ‡Wright, Joseph, F G.S. 4 Alfred-street, Belfast.

Year of Election.

1884. ‡WRIGHT, Professor R. RAMSAY, M.A., B.Sc. Red Gables, Headington Hill, Oxford.
1904. ‡Wright, R. T. Goldieslie, Trumpington, Cambridge.
1911. ‡Wright, W. B., B.A., F.G.S. 14 Hume-street, Dublin.
1903. ‡Wright, William. The University, Birmingham.
1871. ‡WRIGHTSON, Sir THOMAS, Bart., M.Inst.C.E., F.G.S. Neasham Hall, Darlington.
1902. ‡Wyatt, G. H. 1 Maurice-road, St. Andrew's Park, Bristol.
1901. ‡Wylie, Alexander. Kirkfield, Johnstone, N.B.
1902. ‡Wylie, John. 2 Mafeking-villas, Whitehead, Belfast.
1911. ‡Wyllie, W. L., R.A. Tower House, Tower-street, Portsmouth.
1899. ‡WYNNE, W. P., D.Sc., F.R.S. (Pres. B, 1913), Professor of Chemistry in the University of Sheffield. 17 Taptonville-road, Sheffield.

1901. *YAPP, R. H., M.A., Professor of Botany in University College, Aberystwyth.
. *Yarborough, George Cook. Camp's Mount, Doncaster.
1894. *Yarrow, A. F. Campsie Dene, Blanefield, Stirlingshire.
1913. *Yates, H. James, F.C.S., M.I.Mech.E. Redcroft, Four Oaks, Warwickshire.
1905. ‡Yerbury, Colonel. Army and Navy Club, Pall Mall, S.W.
1909. §Young, Professor A. H. Trinity College, Toronto, Canada.
1904. ‡Young, Alfred. Selwyn College, Cambridge.
1891. §YOUNG, ALFRED C., F.C.S. 17 Vicar's-hill, Lewisham, S.E.
1905. ‡Young, Professor Andrew, M.A., B.Sc. South African College, Cape Town.
1909. ‡Young, F. A. 615 Notre Dame-avenue, Winnipeg, Canada.
1913. *Young, Francis Chisholm. La Nonette de la Forêt, Geneva.
1894. *YOUNG, GEORGE, Ph.D. 46 Church-crescent, Church End, Finchley, N.
1909. §Young, Herbert, M.A., B.C.L., F.R.G.S. Arnprior, Ealing, W.
1901. *Young, John. 2 Montague-terrace, Kelvinside, Glasgow.
1885. ‡YOUNG, R. BRUCE, M.A., M.B. 8 Crown-gardens, Dowanhill, Glasgow.
1909. ‡Young, R. G. University of North Dakota, North Chautauqua, North Dakota, U.S.A.
1901. ‡Young, Robert M., B.A. Rathvarna, Belfast.
1883. *YOUNG, SYDNEY, D.Sc., F.R.S. (Pres. B, 1904), Professor of Chemistry in the University of Dublin. 12 Raglan-road, Dublin.
1887. ‡Young, Sydney. 29 Mark-lane, E.C.
1911. §Young, T. J. College of Agriculture, Holmes Chapel, Cheshire.
1907. *YOUNG, WILLIAM HENRY, M.A., Sc.D., Hon. Dr. ès Sc.Math., F.R.S., Professor of the Philosophy and History of Mathematics in the University of Liverpool. La Nonette de la Forêt, Geneva, Switzerland.
1903. ‡Yoxall, Sir J. H., M.P. 67 Russell-square, W.C.

CORRESPONDING MEMBERS.

Year of Election

1887. Professor Cleveland Abbe. Local Office, U.S.A. Weather Bureau, Washington, U.S.A.
1892. Professor Svante Arrhenius. The University, Stockholm. (Bergsgatan 18.)
1913. Dr. O. Backlund. Pulkowa, Russia.
1913. Professor C. Barrois. Université, Lille, France.
1897. Professor Carl Barus. Brown University, Providence, R.I., U.S A.
1887. Hofrath Professor A. Bernthsen, Ph.D. Anilenfrabrik, Ludwigshaten, Germany.
1913. Professor K. Birkeland. Universitet, Christiania.
1890. Professor Dr. L. Brentano. Friedrichstrasse 11, München.
1893. Professor Dr. W. C. Brögger. Universitets Mineralogske Institute, Christiania, Norway.
1894. Professor D. H. Campbell. Stanford University, Palo Alto, California, U.S.A.
1897. M. C. de Candolle. 3 Cour de St. Pierre, Geneva, Switzerland.
1887. Professor G. Capellini. 65 Via Zamboni, Bologna, Italy.
1913. Professor H. S. Carhart. University of Michigan, Ann Arbor, Michigan, U.S.A.
1894. Emile Cartailhac. 5 rue de la Chaîne, Toulouse, France.
1901. Professor T. C. Chamberlin. Chicago, U.S.A.
1894. Dr. A. Chauveau. 7 rue Cuvier, Paris.
1913. Professor R. Chodat. Université, Geneva.
1887. F. W. Clarke. Care of the Smithsonian Institution, Washington, D.C., U.S.A.
1913. Professor H. Conwentz. Elssholzst. 13, Berlin W. 57.
1873. Professor Guido Cora. Via Nazionale 181, Rome.
1889. W. H. Dall, Sc.D. United States Geological Survey, Washington, D.C., U.S.A.
1872. Dr. Yves Delage. Faculté des Sciences, La Sorbonne, Paris.
1901. Professor G. Dewalque. 17 rue de la Paix, Liège, Belgium.
1913. Professor Carl Diener. Universität, Vienna.
1876. Professor Alberto Eccher. Florence.
1894. Professor Dr. W. Einthoven. Leiden, Netherlands.
1892. Professor F. Elfving. Helsingfors, Finland.
1901. Professor J. Elster Wolfenbüttel, Germany.
1913. Professor A. Engler. Universität, Berlin.
1913. Professor Guilio Fano. Istituto di Fisiologia, Florence.
1901. Professor W. G. Farlow. Harvard, U.S.A.
1874. Dr. W. Feddersen. Carolinenstrasse 9, Leipzig.
1913. Professor Chas. Féry. École Municipale de Physique et de Chimie Industrielles, 42 rue Lhomond, Paris.
1886. Dr. Otto Finsch. Altewiekring, No. 19b, Braunschweig, Germany.
1894. Professor Wilhelm Foerster, D.C.L. Encke Platz 3A, Berlin, S.W. 48.

Year of Election.

1872. W. de Fonvielle. 50 rue des Abbesses, Paris.
1901. Professor A. P. N. Franchimont. Leiden, Netherlands.
1894. Professor Léon Fredericq. 20 rue de Pitteurs, Liège, Belgium.
1913. Professor M. von Frey. Universität, Würzburg.
1887. Professor Dr. Anton Fritsch. 66 Wenzelsplatz, Prague, Bohemia.
1892. Professor Dr. Gustav Fritsch. Berlinerstrasse 30, Berlin.
1881. Professor C. M. Gariel. 6 rue Edouard Détaille, Paris.
1901. Professor Dr. H. Geitel. Wolfenbüttel, Germany.
1889. Professor Gustave Gilson. l'Université, Louvain, Belgium.
1913. Professor E. Gley. 14 rue Monsieur le Prince, Paris.
1889. A. Gobert. 222 Chaussée de Charleroi, Brussels.
1884. General A. W. Greely, LL.D. War Department, Washington, U.S.A.
1913. Professor P. H. von Groth. Universität, Munich.
1892. Dr. C. E. Guillaume. Bureau International des Poids et Mesures, Pavillon de Breteuil, Sèvres.
1913. Yves Guyot. 95 rue de Seine, Paris.
1876. Professor Ernst Haeckel. Jena.
1881. Dr. Edwin H. Hall. 30 Langdon-street, Cambridge, Mass., U.S.A.
1913. Professor A. Haller. 10 rue Vauquelin, Paris.
1913. Professor H. J. Hamburger. Physiological Institute, Gröningen.
1893. Professor Paul Heger. 23 rue de Drapiers, Brussels.
1894. Professor Ludimar Hermann. Universität, Königsberg, Prussia.
1893. Professor Richard Hertwig. Zoologisches Institut, Alte Akademie, Munich.
1897. Dr. G. W. Hill. West Nyack, New York, U.S.A.
1913. Dr. P. P. C. Hoek, Universiteit, Haarlem.
1913. Professor A. F. Holleman. Universiteit, Amsterdam.
1881. Professor A. A. W. Hubrecht, LL.D., D.Sc., C.M.Z.S. The University, Utrecht, Netherlands.
1887. Dr. Oliver W. Huntington. Cloyne House, Newport, R.I., U.S.A.
1884. Professor C. Loring Jackson. 6 Boylston Hall, Cambridge, Massachusetts, U.S.A.
1876. Dr. W. J. Janssen. Soldino, Lugano, Switzerland.
1881. W. Woolsey Johnson, Professor of Mathematics in the United States Naval Academy, Annapolis, Maryland, U.S.A.
1887. Professor C. Julin. 159 rue de Fragnée, Liège.
1876. Dr. Giuseppe Jung. Bastions Vittoria 41, Milan.
1913. Professor Hector Jungersen. Universitet, Copenhagen.
1913. Professor J. C. Kapteyn. Universiteit, Gröningen.
1913. Professor A. E. Kennelly. Harvard University, Cambridge, Massachusetts, U.S.A.
1884. Baron Dairoku Kikuchi, M.A. Imperial University, Tokyo, Japan.
1873. Professor Dr. Felix Klein. Wilhelm-Weberstrasse 3, Göttingen.
1894. Professor Dr. L. Kny. Kaiser-Allee 186–7, Wilmersdorf, bei Berlin.
1894. Professor J. Kollmann. St. Johann 88, Basel, Switzerland.
1913. Professor D. J. Korteweg. Universiteit, Amsterdam.
1913. Professor A. Kossel. Physiologisches Institut, Heidelberg.
1894. Maxime Kovalevsky. 13 Avenue de l'Observatoire, Paris, France.
1877. Dr. Hugo Kronecker, Professor of Physiology. Universität, Bern, Switzerland.
1913. Ch. Lallemand, Directeur-Général des Mines. 58 Boulevard Emile-Augier, Paris.
1887. Professor J. W. Langley. 2037 Geddes-avenue, Ann Arbor, Michigan, U.S.A.
1872. M. Georges Lemoine. 76 rue Notre Dame des Champs, Paris.
1901. Professor Philipp Lenard. Schlossstrasse 7, Heidelberg.

Year of Election.

1887. Professor A. Lieben. Molkerbastei 5, Vienna.
1883. Dr. F. Lindemann. Franz-Josefstrasse 12/I, Munich.
1887. Professor Dr. Georg Lunge. Rämistrasse 56, Zurich, V.
1913. Professor F. von Luschan. Universität, Berlin.
1894. Professor Dr. Otto Maas. Universität, Munich.
1887. Henry C. McCook, D.D., Sc.D., LL.D. 3700 Chestnut-street, Philadelphia, U.S.A.
1913. Professor E. Mahaim. Université de Liège, Belgium.
1887. Dr. C. A. von Martius. Voss-strasse 8, Berlin, W.
1884. Professor Albert A. Michelson. The University, Chicago, U.S.A.
1887. Dr. Charles Sedgwick Minot. Boston, Massachusetts, U.S.A.
1894. Professor G. Mittag-Leffler. Djursholm, Stockholm.
1897. Professor Oskar Montelius. St. Paulsgatan 11, Stockholm, Sweden.
1913. Professor E. H. Moore. University of Chicago, U.S.A.
1897. Professor E. W. Morley, LL.D. West Hartford, Connecticut, U.S.A.
1887. E. S. Morse. Peabody Academy of Science, Salem, Mass., U.S.A.
1913. Professor F. R. Moulton. University of Chicago, U.S.A.
1889. Dr. F. Nansen. Lysaker, Norway.
1894. Professor R. Nasini. Istituto Chimico, Via S. Maria, Pisa, Italy.
1913. Professor E. Naville. Université, Geneva.
1887. Professor Emilio Noelting. Mühlhausen, Elsass, Germany.
1894. Professor H. F. Osborn. Columbia College, New York, U.S.A.
1890. Professor W. Ostwald. Linnéstrasse 2, Leipzig.
1890. Maffeo Pantaleoni. 13 Cola di Rienzo, Rome.
1895. Professor F. Paschen. Universität, Tübingen.
1887. Dr. Pauli. Feldbergstrasse 49, Frankfurt a/Main, Germany.
1901. Hofrath Professor A. Penck. Georgenstrasse 34–36, Berlin, N.W. 7.
1890. Professor Otto Pettersson. Stockholms Hogskola, Stockholm.
1894. Professor W. Pfeffer, D.C.L. Linnéstrasse 11, Leipzig.
1886. Professor F. W. Putnam. Harvard University, Cambridge, Massachusetts, U.S.A.
1887. Professor Georg Quincke. Bergstrasse 41, Heidelberg.
1868. L. Radlkofer, Professor of Botany in the University of Munich. Sonnenstrasse 7.
1913. Professor Reinke. Universität, Kiel.
1895. Professor Ira Remsen. Johns Hopkins University, Baltimore, U.S.A.
1913. Dr. Hans Reusch. Universitet, Christiania.
1897. Professor Dr. C. Richet. 15 rue de l'Université, Paris, France.
1896. Dr. van Rijckevorsel. Parklaan 3, Rotterdam, Netherlands.
1892. Professor Rosenthal, M.D. Erlangen, Bavaria.
1913. Professor A. Rothpletz. Universität, Munich.
1913. Professor H. Rubens. Universität, Berlin.
1895. Professor Carl Runge. Wilhelm Weberstrasse 21, Göttingen, Germany.
1901. Gen.-Major Rykatchew. Perspective Sredny 34, Wass. Ostr., St. Petersburg.
1913. Dr. C. Schoute. De Biet, Holland.
1874. Dr. G. Schweinfurth. Kaiser Friedrichstrasse 8, Berlin.
1897. Professor W. B. Scott. Princeton, N.J., U.S.A.
1887. Professor H. Graf Solms. Botanischer Garten, Strassburg.
1887. Ernest Solvay. 25 rue du Prince Albert, Brussels.
1888. Dr. Alfred Springer. 312 East 2nd-street, Cincinnati, Ohio, U.S.A.
1881. Dr. Cyparissos Stephanos. The University, Athens.

Year of Election.

1887. Professor John Trowbridge. Harvard University, Cambridge, Massachusetts, U.S.A.

1889. Wladimir Vernadsky. Imperial Academy of Sciences, St. Petersburg.

1913. Professor M. Verworn. Universität, Bonn.

1886. Professor Jules Vuylsteke. 21 rue Belliard, Brussels, Belgium.

1887. Professor Dr. Leonhard Weber. Moltkestrasse 60, Kiel.

1913. Professor Max Weber. Universiteit, Amsterdam.

1887. Professor August Weismann. Freiburg-im-Breisgau, Baden.

1887. Dr. H. C. White. Athens, Georgia, U.S.A.

1881. Professor H. M. Whitney. Branford, Conn., U.S.A.

1887. Professor E. Wiedemann. Erlangen.

1887. Professor Dr. R. Wiedersheim. Hansastrasse 3, Freiburg-im-Breisgau, Baden.

1887. Dr. Otto N. Witt. Ebereschen-Allée 10, Westend bei Berlin.

1913. Professor R. W. Wood. Johns Hopkins University, Baltimore, U.S.A.

1896. Professor E. Zacharias. Botanischer Garten, Hamburg.

1913. Professor P. Zeeman. Universiteit, Amsterdam.

LIST OF SOCIETIES AND PUBLIC INSTITUTIONS

TO WHICH A COPY OF THE REPORT IS PRESENTED.

GREAT BRITAIN AND IRELAND.

Belfast, Queen's University.
Birmingham, Midland Institute.
Bradford Philosophical Society.
Brighton Public Library.
Bristol Naturalists' Society.
——, The Museum.
Cambridge Philosophical Society.
Cardiff, University College.
Chatham, Royal Engineers' Institute.
Cornwall, Royal Geological Society of.
Dublin, Geological Survey of Ireland.
——, Royal College of Surgeons in Ireland.
——, Royal Irish Academy.
——, Royal Society.
——, National Library of Ireland.
Dundee, University College.
Edinburgh, Royal Society of.
——, Royal Medical Society of.
——, Scottish Society of Arts.
Exeter, Royal Albert Memorial College Museum.
Glasgow, Royal Philosophical Society of.
——, Institution of Engineers and Shipbuilders in Scotland.
Leeds, Institute of Science.
——, Philosophical and Literary Society of.
Liverpool, Free Public Library.
——, Royal Institution.
——, The University.
London, Admiralty, Library of the.
——, Board of Agriculture and Fisheries.
——, Chemical Society.
——, Civil Engineers, Institution of.
——, Geological Society.
——, Geology, Museum of Practical.
——, Greenwich Royal Observatory.
——, Guildhall Library.
——, Institution of Electrical Engineers.
——, Institution of Mechanical Engineers.
London, Intelligence Office, Central Department of Political Information.
——, King's College.
——, Linnean Society.
——, London Institution.
——, Meteorological Office.
——, Physical Society.
——, Royal Anthropological Institute.
——, Royal Asiatic Society.
——, Royal Astronomical Society.
——, Royal College of Physicians.
——, Royal College of Surgeons.
——, Royal Geographical Society.
——, Royal Institution.
——, Royal Meteorological Society.
——, Royal Sanitary Institute.
——, Royal Society.
——, Royal Society of Arts.
——, Royal Statistical Society.
——, United Service Institution.
——, University College.
——, War Office, Library.
——, Zoological Society.
Manchester Literary and Philosophical Society.
——, Municipal School of Technology.
Newcastle-upon-Tyne, Literary and Philosophical Society.
——, Public Library.
Norwich, The Free Library.
Nottingham, The Free Library.
Oxford, Ashmolean Natural History Society.
——, Radcliffe Observatory.
Plymouth Institution.
——, Marine Biological Association.
Salford, Royal Museum and Library.
Sheffield, University College.
Southampton, Hartley Institution.
Stonyhurst College Observatory.
Surrey, Royal Gardens, Kew.
——, Kew Observatory, Richmond.
Swansea, Royal Institution of South Wales.
Yorkshire Philosophical Society.
The Corresponding Societies.

EUROPE

Berlin ....Die Kaiserliche Akademie der Wissenschaften.
Bonn ....University Library.
Brussels ....Royal Academy of Sciences.
Charkow ....University Library.
Coimbra .....Meteorological Observatory.
Copenhagen...Royal Society of Sciences.
Dorpat, Russia University Library.
Dresden ....Royal Public Library.
Frankfort ...Natural History Society.
Geneva.......Natural History Society.
Göttingen ....University Library.
Grätz ....Naturwissenschaftlicher Verein.
Halle ....Leopoldinisch-Carolinische Akademie.
Harlem ......Société Hollandaise des Sciences.
Heidelberg....University Library.
Helsingfors ...University Library.
Jena ....University Library.
Kazan, Russia University Library.
Kiel ....Royal Observatory.
Kiev ....University Library.
Lausanne ....The University.
Leiden ....University Library.
Liège ....University Library.
Lisbon ....Academia Real des Sciences.
Milan ....The Institute.
Modena ......Royal Academy.
Moscow ......Society of Naturalists
—— ......University Library.
Munich.......University Library.
Naples ....Royal Academy of Sciences.
—— ....Zoological Station.
Paris.........Association Française pour l'Avancement des Sciences.
—— ....Geographical Society.
—— ....Geological Society.
—— ....Royal Academy of Sciences.
—— ....School of Mines.
Pultova ......Imperial Observatory,
Rome ....Accademia dei Lincei.
—— ....Collegio Romano.
—— ....Italian Geographical Society.
—— ....Italian Society of Sciences.
Roumania ..Roumanian Association for the Advancement of Science.
St. Petersburg. University Library.
—— ....Imperial Observatory.
Spain ....Asociasion para el Progreso de las Ciencias.
Stockholm ...Royal Academy.
Turin ....Royal Academy of Sciences.
Upsala ......Royal Society of Science.
Utrecht ......University Library.
Vienna ......The Imperial Library.
—— ....Central Anstalt für Meteorologie und Erdmagnetismus.
Zurich........Naturforschende Gesellschaft.

ASIA.

Agra ....The College.
Bombay .....Elphinstone Institution.
—— ....Grant Medical College.
Calcutta .....Asiatic Society.
—— ....Hooghly College.
Calcutta .....Medical College.
—— ....Presidency College.
Ceylon ....The Museum, Colombo.
Madras ......The Observatory.
—— ....University Library.
Tokyo ....Imperial University.

AFRICA.

Cape Town ....The Royal Observatory.
—— ....South African Association for the Advancement of Science.
—— ....South African Public Library.
Grahamstown ..Rhodes University College.
Kimberley ....Public Library.

AMERICA.

Albany ......The Institute.
Amherst......The Observatory.
Baltimore ....Johns Hopkins University.
Boston ......American Academy of Arts and Sciences.
—— ....Boston Society of Natural History.
California.....The University.
—— ......Lick Observatory.
—— ......Academy of Sciences.
Cambridge ...Harvard University Library.
Chicago ......American Medical Association.
—— ....Field Museum of Natural History.
Kingston .....Queen's University
Manitoba ....Historical and Scientific Society.
—— ....The University.
Massachusetts .Marine Biological Laboratory, Woods Holl.
Mexico ......Sociedad Científica 'Antonio Alzate.'
Missouri .....Botanical Garden
Montreal .....Council of Arts and Manufactures.
Montreal .....McGill University.
New York ...American Society of Civil Engineers.
—— ....Academy of Sciences.
Ottawa.......Geological Survey of Canada.
Philadelphia ..American Philosophical Society.
—— ....Franklin Institute.
—— ....University of Pennsylvania.
Toronto .....The Observatory.
—— ....The Canadian Institute.
—— ....The University.
Uruguay......General Statistical Bureau and Library, Montevideo.
Washington...Board of Agriculture.
—— ....Bureau of Ethnology.
—— ....Bureau of Standards, Department of Commerce and Labour.
—— ....Coast and Geodetic Survey.
—— ....Library of Congress.
—— ....Naval Observatory.
—— ....Smithsonian Institution.
—— ....United States Geological Survey of the Territories.

AUSTRALIA.

Adelaide ... .Public Library of South Australia.
—— ....Royal Geographical Society.
Brisbane ....Queensland Museum
—— .. .. Queensland Public Library.
Melbourne ...... .Public Library.
Sydney ....Public Works Department.
—— . ...Australian Museum
—— ....Library, Department of Mines.
Tasmania ....Royal Society.
Victoria............The Colonial Government.

NEW ZEALAND.

Canterbury ....The Museum.
Wellington ....New Zealand Institute (Dominion Museum).

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